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GCA Corp, Bedford, Mass GCA Technology Div

Prepared for

Environmental Protection Agency, Research Triangle Park, N C Office of Air Quality Planning and Standards

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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume XVI - Providence

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National Assessment of the Urban Particulate Problem: Volume XVI - Providence

June 1976

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Office of Air Quality Planning and Standards
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Final

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This document is one volume of a sixteen-volume report presenting an overall assessment of the particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of fourteen study-area volumes that provide working summaries of data gathered in the fourteen urban areas studied. These city reports primarily provide documentation and background information for Volume I of the study - National Assessment of the Particulate Problem - Final Report. Volume I should be considered the primary output of the report.

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NATIONAL ASSESSMENT OF THE URBAN PARTICULATE PROBLEM

Volume XVI
Providence, Rhode Island

FINAL REPORT

by
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Contract No. 68-02-1376, Task Order No. 18

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Prepared for

ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

June 1976

This final report was furnished to the Environmental Protection Agency by the OCA/Technology Division in fulfillment of the requirements under Contract No. 68-02-1376, Task Order No. 18. The contents of this report are reproduced herein as received from the contractor. The opinions, findings and conclusions are those of the authors and not necessarily those of the Environmental Protection Agency.

FOREWORD

This document is part of a 16-volume report assessing the urban particulate problem, which was conducted by GCA/Technology Division for EPA.

This particular document is one of the 14 single city volumes that provide working summaries of data collected in the 14 urban areas during 1974 to support an assessment of the general nature and extent of the TSP problem nationwide. No attempt was made to perform detailed or extensive analyses in each urban area. Rather, the city reports are intended as a collection of pertinent data which collectively form a profile of each urban area. Info, in turn contributes to a comparative analysis of data among the 14 areas in an attempt to identify general patterns and factors relating to attainment of the TSP problem nationwide. Such an analysis has been made in Volume I of the study-National Assessment of the Urban Particulate Problem-National Assessment. The reader is referred to this volume as the summary document where the data is collectively analyzed.

This and the other 13 city reports are viewed primarily as working documents; thus, no effort was made to incorporate all the reviewer's comments into the text of the report. The comments were, however, considered during the preparation of Volume I and are included herein in order to alert the reader to different points of view. The 16 volumes comprising the overall study are as follows:

Volume	I = National Assessment of the Urban Particulate Problem
Volume	II = Particle Characterization
Volume	III = Denver
Volume	IV = Birmingham
Volume	V = Baltimore
Volume	VI = Philadelphia
Volume	VII = Chattanooga
Volume	IX = Oklahoma City
Volume	X = Seattle
Volume	XI = Cincinnati
Volume	XII = Cleveland
Volume	XIII = San Francisco
Volume	XIV = Miami
Volume	XV = St. Louis
Volume	XVI = Providence

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EXECUTIVE SUMMARY

AIR QUALITY LEVELS AND TRENDS

Concentrations of TSP throughout Rhode Island are generally less than the national annual standards and 24-hour standards — in 1974 only five of 31 sites were not attaining the national annual standard and the 24-hour secondary standard was exceeded on less than 1 percent of the sample-days. Air quality has been improving since 1965 — annual TSP mean concentrations have decreased by 25 $\mu g/m^3$ at the rural and suburban sites and by 60 $\mu g/m^3$ at the urban site. Most of the sampling sites in the AQCR have never had a problem attaining the national standards for particulates. This is due to the proximity of the ocean and undeveloped land, frequent rainfall, and the low level and lack of concentration of industrial activity. Other sites have recently attained the standards due to events such as the economic decline and the energy crisis, and to the imposition of the incinerator and low-sulfur fuel regulations.

The five sites not attaining the national annual standards are all located in the metropolitan area and all but one in the center city. The reasons for these sites' nonattainment are nearby construction activity, urban background due to traffic and oil-fired space heating, and in one case, unusual siting in close proximity to a major expressway.

REGIONAL SETTING

The Providence AQCR lies in the southeastern section of New England. Prominent features of the AQCR are its proximity to the Atlantic Ocean,

Narragansett Bay, rolling land bordering the coast, and hilly upland in the northwestern third of Rhode Island. The city of Providence is located on the northern portion of the Bay. There is generally good ventilation by air masses having low background particulate levels. Precipitation occurs frequently and moderately, averaging about 40 inches per year. Temperatures are moderated by the proximity to the ocean, averaging near 29°F in the winter and 73°F in the summer. Providence is in a favorable location, compared to other cities, with respect to pollution potential. Though Rhode Island is densely populated, there is a low level of heavy industrial activity and no areas of industrial concentration.

EMISSIONS

The overall emission levels and density are low, even in the most congested areas -- the highest emission density, found in the central business district, is approximately 50 TPY per square mile. Inventoried emissions are estimated to be 10,000 TPY in Rhode Island.

There is no area where industry is concentrated and the level of industrial activity is low. Process emissions are insignificant (less than 6 percent of the inventoried emissions). Area source emissions, including fuel combustion, incineration and urban fugitive dust, are a large part of the total emissions. About two-thirds of the inventoried emissions are from area sources, but fugitive dust, which is probably an important portion, is uninventoried.

Emissions of particulates have generally been decreasing over the past few years. Rhode Island has been experiencing an economic decline in addition to the energy crisis. Fuel usage gradually changed from coal to oil from the 1950's to 1967.

REGULATIONS

The primary abatement tool is the Visible Emission Evaluation (VEE). Calculations of emissions are used to judge compliance. Stack tests and routine process inspections are utilized less frequently. Regulations for fugitive dust and fuel combustion could be expanded if needed, but the present air quality does not seem to require it.

Enforcement of the incinerator regulation has closed many small incinerators and forced larger ones to abate or be replaced. The low-sulfur fuel regulation has also been enforced.

METEOROLOGY

The frequent and moderate rainfall tends to wash particulates from the air and to suppress resuspension of dust. Variations in annual TSP concentrations tend to follow variations in annual rainfall from year to year. Due to the moderately cold winters, a substantial amount of fuel combustion is required for heating -- Rhode Island averages 6,000 heating degree days per year.

Analysis of pollutant roses shows that TSP concentrations are higher when winds are from the south to west, the direction associated with incoming air masses which have passed over the eastern seaboard. TSP concentrations are lower when winds are from the northwest or the east to northeast, the directions associated with fresh polar air and storms, respectively.

URBAN ACTIVITY

The annual TSP concentrations for the center city sites in Providence are related to such urban activities as the types of land use around the sites (residential and commercial, industrial, parks and open space, and transportation-related), the volume of traffic on nearby streets, and nearby construction activity. Annual TSP concentrations were higher in areas where activity was greater and urban in nature.

NETWORK DESIGN AND MONITOR SITING

The overall set of sampling sites located throughout the state adequately represents the various regions in the state. There are minor problems with the location and representativeness of three of the center city sampling sites and with the height of the monitors through the entire network. The one site (Dyer Street, No. 42) which exceeds the annual primary standard appears to be influenced by fugitive road dust and traffic emissions due to its proximity to a major highway. The exposure of another site is limited because it is six stories above the street and surrounded by taller buildings. A third site is located some distance from the central business district so its representativeness as a CBD site is questionable, though it is adequate as an urban site. Monitor height ranges from 15 feet to 100 feet with most in the 30 to 50 foot range.

REVIEWERS' COMMENTS

The draft report for each city was submitted to interested EPA, state, and local officials for comment on the contents and findings. Comments of an editorial nature were reconciled; comments of a substantive nature which reflect differences of opinion were compiled and are presented below.

General - The document implies that there has been little noticeable effect from regulations on particulate air quality. The reviewers disagree.

Page 8 - Air quality improvements cited have been based on National Air Surveillance Network sites.

Page xii - The agency makes some use of routine process inspections to judge compliance.

Page xiii - The agency notes that the monitoring network is oriented towards urban sites.

Page 4 - The agency feels there may be other influences on the monitoring sites than the ones postulated.

Page 14 - The agency questions the thoroughness of the NEDS data.

Page 18 - The agency questions the data base used in the discussion on smoke detection.

SECTION I

AIR QUALITY SUMMARY

The Division of Air Pollution Control of the Rhode Island State Department of Health currently samples for total suspended particulates at 21 sites in the state, three of which are NASN sites. The network is primarily oriented toward sampling in suburban areas - only four center-city monitors are located outside of Providence and one monitor, a NASN station, is in a rural area. All of the monitors are considered to be in population-oriented locations. The height above ground of the monitors varies from ground level (3 feet) to seven stories (over 100 feet). Most of the monitors are in the 20 to 30 foot height range and most are located on flat-roofed public buildings.

The general pattern of particulate concentrations is concentric about the metropolitan area, with most of the sites at or below the annual secondary standard of 60 $\mu g/m^3$. Out of the 21 monitors in the state in 1974, only one site (number 42 on Dyer Street in Providence) exceeded the national annual primary standard of 75 $\mu g/m^3$ while four sites exceeded the annual secondary standard. The 24-hour secondary standard was exceeded eight times, at a total of six stations, out of 966 total observations. All of the violations of the standards occurred at sampling sites in the center-city area of metropolitan Providence.

The 1974 annual geometric means for TSP in Rhode Island are plotted at their respective sampling sites in Figure 1 and for the Providence area in Figure 2. These figures indicate that at no sites outside of the metropolitan Providence area are the concentrations greater than 50 $\mu g/m^3$

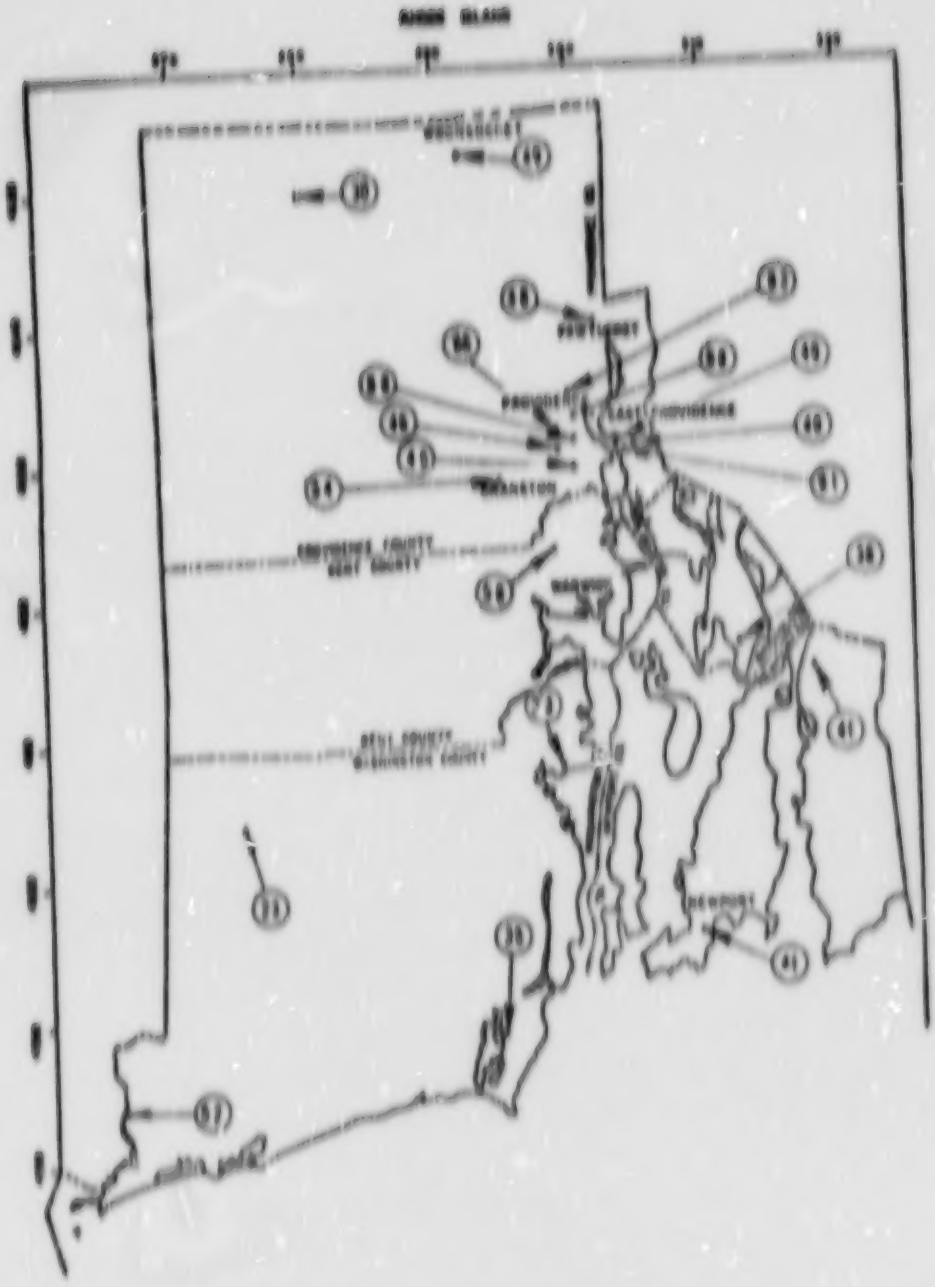


Figure 1. 1974 annual geometric mean TSP concentrations

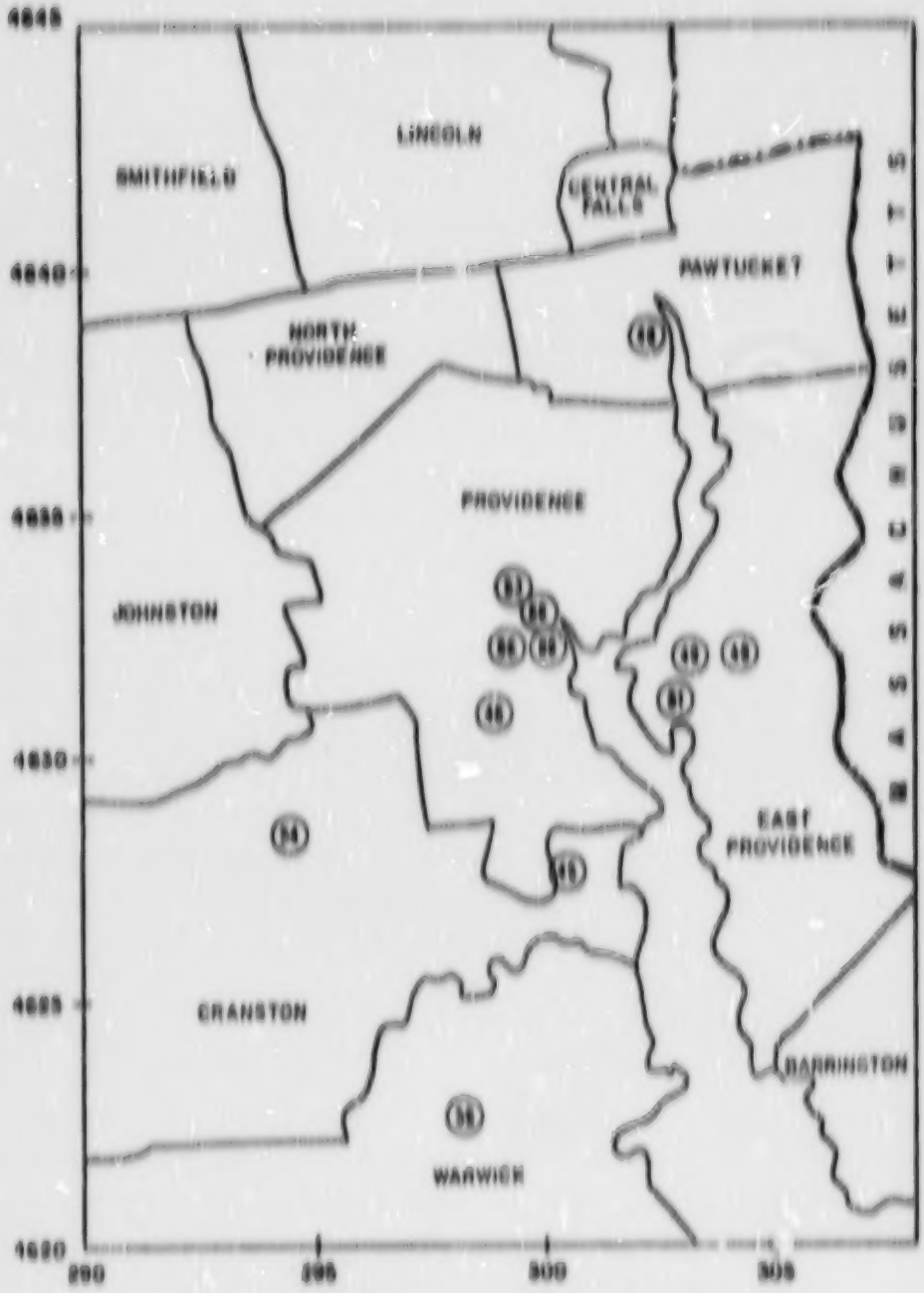


Figure 2. 1974 annual geometric mean TSP concentrations, Providence Metropolitan Area

and that many sites are on the order of 30 to 40 $\mu g/m^3$, with the rural NASN station sampling an average of only 23 $\mu g/m^3$.

The only stations operating prior to 1969 were the three NASN stations, two of which are located in the Providence metropolitan area and one in a rural setting. The annual geometric means for these three stations are plotted in Figure 3 to indicate the trends in particulate concentrations over time. There has been a noticeable downtrend since the mid-1960's, and not only do the concentrations at the two metropolitan stations appear to follow a reasonably consistent pattern, but the rural station, number 54, also generally follows the same pattern. While the reduction in ambient TSP concentrations at the Providence Station was about 60 $\mu g/m^3$ between 1965 and 1973, which might be attributed to reductions in emissions, the concentrations at the nearby East Providence station have been reduced only about 25 $\mu g/m^3$, which is approximately the same reduction as at the Exeter monitor, considered to be measuring background concentrations.

Most of the Rhode Island sampling sites have never had problems attaining the national standards for particulates. This is due to the proximity of the ocean and undeveloped land, frequent rainfall, and the low level and lack of concentration of industrial activity. Other sites have recently attained the standards due to events such as the economic decline and the energy crisis, and to the imposition of the incinerator and low-sulfur fuel regulations.

Of the 21 sites where particulates are being monitored, four are not meeting the national annual secondary standard and one is not meeting the national annual primary standard. All but one of these sites are located in the center city. The reasons for these sites' nonattainment are nearby construction activity, urban background due to traffic and oil-fired space heating, and in the case of the Dyer Street site (No. 42), unusual siting in close proximity to a major expressway.

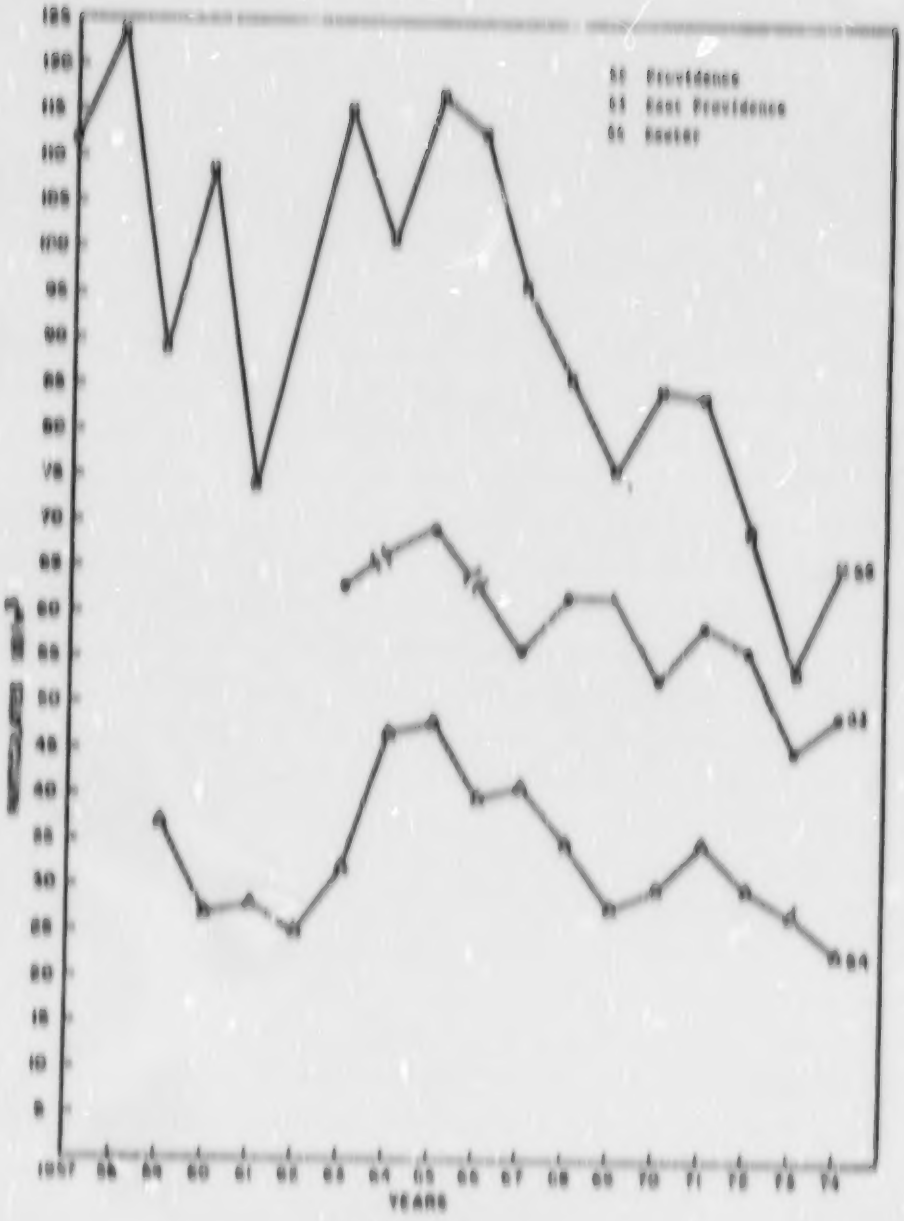


Figure 3. Trends in annual geometric mean TSP concentrations

SECTION II

ANALYSES

METEOROLOGY AND CLIMATOLOGY

The climate experienced in Rhode Island, particularly the very frequent rainfall, appears to be a significant and relatively constant factor in determining TSP levels. Frequent rainfall tends to wash particulates out of the atmosphere, to cleanse the streets, and to suppress resuspension of fugitive dust. In fact, rainfall appears to be partially responsible for some of the trends observed in average annual TSP concentrations. Lower than average amounts of rainfall were matched by peaks in the annual geometric mean TSP concentration trends at the Providence NASN station in the years 1960, 1963 through 1966, and 1971 (see Figures 3 and 4). The opposite case of higher than average rainfall matched by dips in the TSP trends is shown in the years 1962, 1967, and 1973. Areawide trends in TSP concentrations can also be tied to trends in annual rainfall. In 1971, 16 of the 19 sampling sites showed an average increase of 15 $\mu g/m^3$ over the 1970 annual geometric mean TSP concentrations (see Figures 15 through 20). Analysis of the 1971 rainfall showed that a lower than average amount fell and that sampling tended to occur on dry days (samples were taken on 14.2 percent of the days and only 10.9 percent of the rain fell on those days). In 1972, an average decrease of 17 $\mu g/m^3$ occurred at 19 of the 20 sampling sites. A 50 percent increase in rainfall occurred that year.

An analysis of rainfall as it influences TSP concentrations at two sites is shown in Figure 5. A line was drawn encompassing the uppermost points

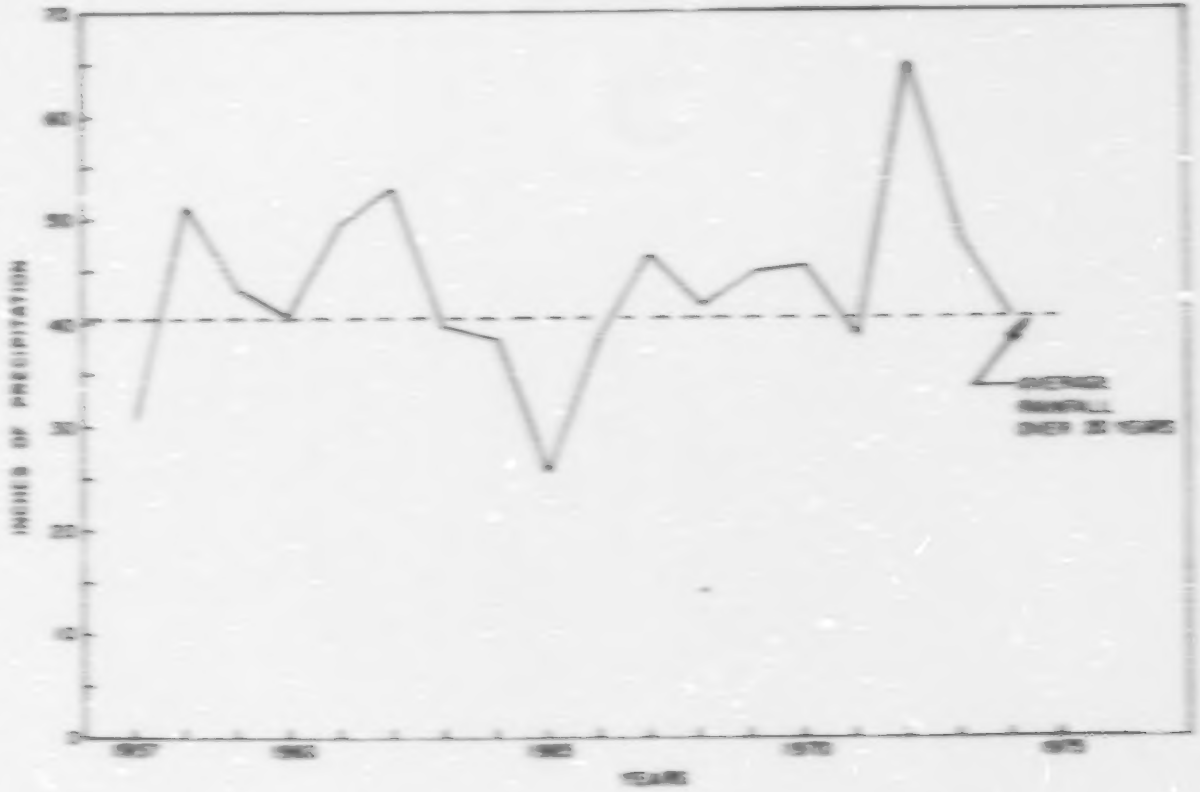


Figure 4. Annual rainfall

Table 1. SAMPLING SITE CHARACTERISTICS

SAROAD code	Town	Address	Height, feet	Open distance in direction, feet	Distance to road, highest traffic volume, feet	Site elevation, above mean sea level, feet	Site characteristics	Town influences on air quality trends
1	Providence	State Office Building	10	214		43	CBD	General urban (+CBD), east northeast
11	Providence	Westminster Street	10	214		43	CBD	Open parking, northeast to taller buildings
42	Providence	Dyer School	11	42		80	CBD	Bricks refineries, east power plant
46	E. Providence	Thomas Burgin School	10			41	residential	General urban activity, regional transp.
47	Cranston	General Hospital	10			41	residential	Residential area activity
48	Providence	St. Joseph's Hospital	10	30		40	residential	Residential area activity
50	Providence	Police Station	45	45		40	CBD	General urban activity, east northeast
51	E. Providence	Jr. High School	45			40	commercial residential	Commercial area activity

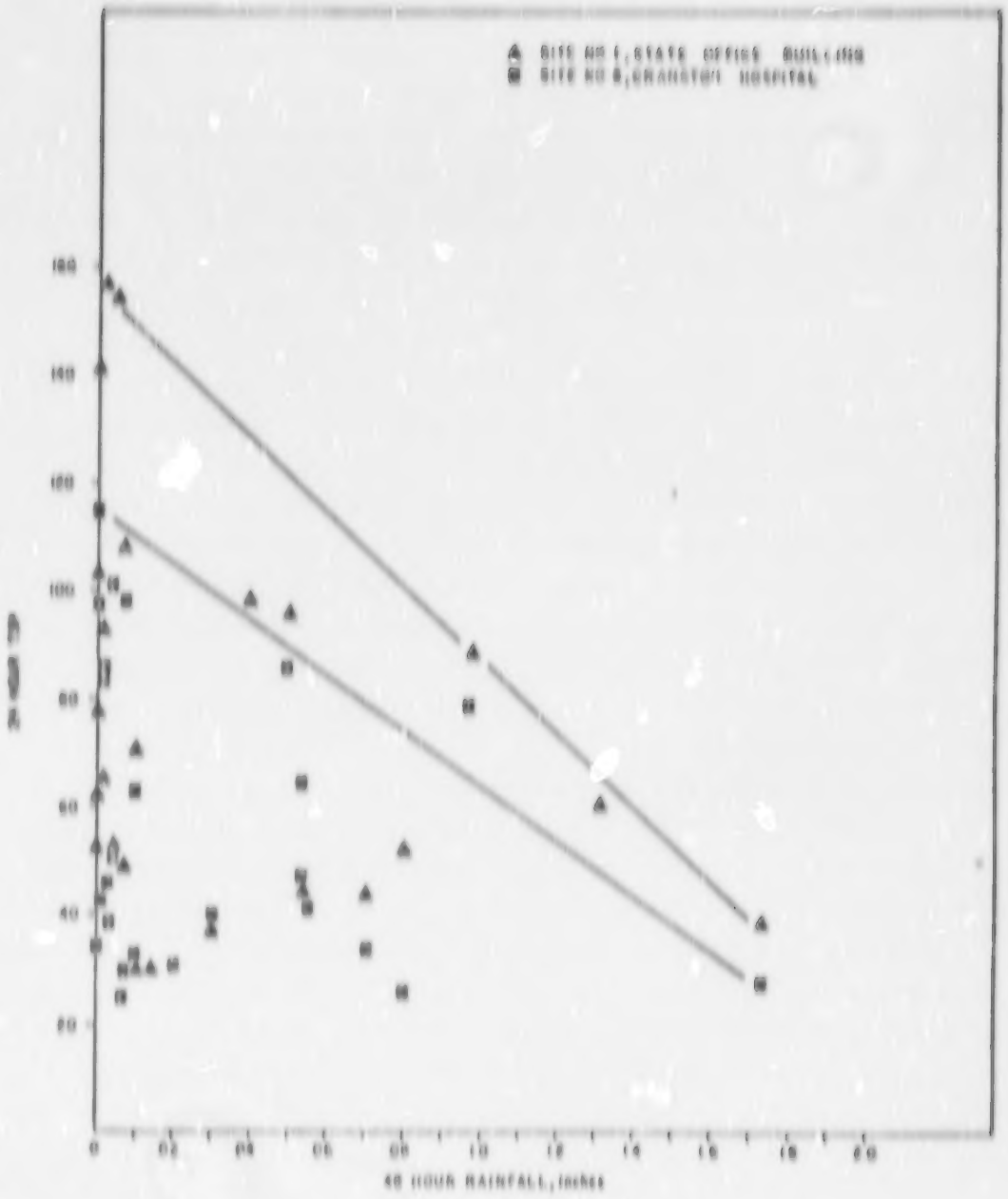


Figure 5. Rainfall versus TSP concentrations

for each site and an inverse relationship between the amount of rainfall and the highest TSP concentrations can be seen. The difference in the upper limits for the two sites is due to the fact that the center-city site (the State Office Building) is influenced by high urban TSP concentrations, whereas the other (Cranston General Hospital) is in a suburban residential area. The large number of TSP readings below the upper limits were probably influenced by one or more of the factors, such as emissions, which tend to decrease TSP concentrations. The upper limits of TSP seem to be determined by rainfall when these other factors are not determining the amount of TSP in the atmosphere.

In New England, winds from the south to west are usually coming from a Bermuda high and indicate an older air mass, the trajectory of which has been over the Eastern seaboard. Winds from the northwest are associated with incoming high pressure systems and fresh polar air, while winds from the east to northeast are associated with "northeasterly" storms, especially in the winter. These meteorological patterns generally coincide with the pollutant roses constructed for several of the Rhode Island sampling sites. Pollutant roses for five sites in the metropolitan area are shown in Figure 6 and for three sites outside the metropolitan area in Figure 7. At all of the sites, TSP concentrations are slightly higher when the wind is from the south to west and lower when the wind is from the north to east. Thus, although the pollutant roses for the center-city sites showed that generally, mean TSP contributions were higher for winds coming from the southwest to west sector, it is not necessarily a function of local land use and sources. At the Cranston Police Station (site #8), to the southwest and hence upwind of Providence, and generally downwind from undeveloped areas, mean TSP concentrations were also higher for winds coming from the south to the west. This indicates that these directional effects are more regional in nature and likely a function of the meteorology.

The pollutant roses also indicate local directional effects. The barbs of the pollutant roses become longer nearer the metropolitan area,

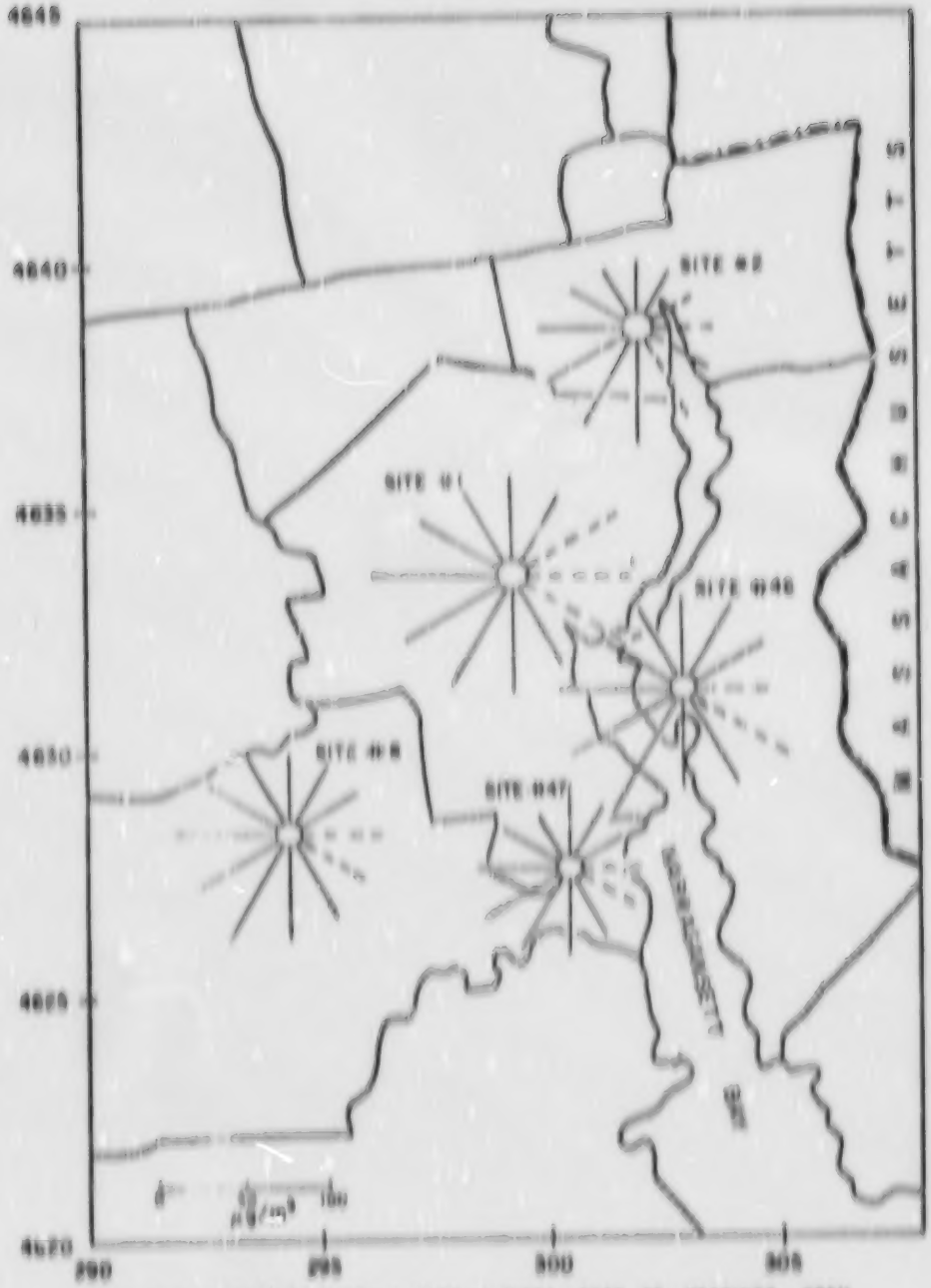
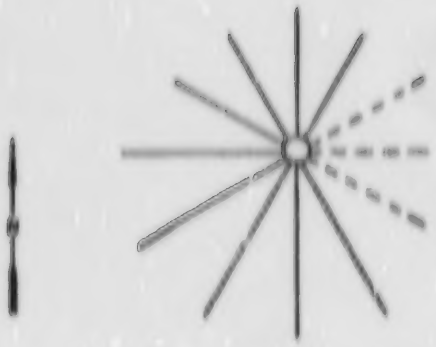
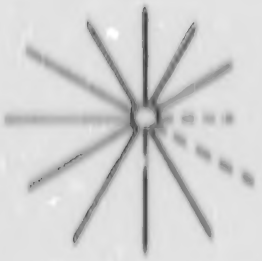


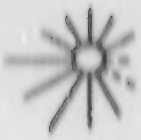
Figure 6. Pollutant roses for Providence Metropolitan Area



SITE NO. 48
OVER STREET
PROVIDENCE



SITE NO. 19
WESTMINSTER
STREET
PROVIDENCE



SITE NO. 80
JUNIOR HIGH SCHOOL
NARRAGANSETT

NOTE: DASHED BARS INDICATES A MORE LIMITED BASE OF READINGS FROM THAT DIRECTION.

Figure 7. Three pollutant roses

indicating that particulates tend to be picked up in suburban and urban areas as air flows by toward the city and away from it after passing through it. The barbs for the Naraganasett (site 50) pollutant rose are short compared to other sites, due to the proximity to the ocean and undeveloped areas. The Dyer Street rose has the longest barbs, strongly influenced by the presence of an expressway to the south to southwest.

Rhode Island experiences moderate winters, averaging about 6000 heating degree days per year. There is no massive seasonal pattern in TSP concentration, although a significant amount of fuel combustion is required for heating. The slight changes in heating load over the last few years are too small to be seen in the TSP concentrations.

Emissions Analysis

Based on the emission levels in Providence County given in NEDS (base year 1972), the area source emissions are about twice the point source emissions in the Region and the most important type of area source emissions is fuel combustion by residential, industrial and commercial-/institutional sources (see Table 2). The other major types of sources according to NEDS are transportation and solid waste disposal. (The contribution from solid waste disposal is believed to have declined since the time of the inventory due to the incinerator regulations.) There are no areas in Rhode Island which could be considered highly industrialized, including Providence County which accounts for 90 percent of the industrial process emissions in the state but in which the process emissions are only 4.7 percent of the total particulate emissions.

A major element of the TSP which is unmentioned is urban fugitive dust. This comes primarily from traffic entrained dust particles, construction activity, and general urban living and is further explained in the urban activity analysis section.

Table 2. NEDS EMISSIONS FOR PROVIDENCE COUNTY

	Providence County			
	Point	Area	Total	Total as % of grand total
Fuel combustion	(1,149)	(3,558)	(4,707)	(47.6)
Residential		757	757	7.7
Electrical	475		475	4.8
Industrial	618	1,108	1,726	17.5
C-I	56	1,693	1,749	17.7
Industrial process	(581)		(581)	(4.7)
Chemical				
Metals	112		112	0.3
Mineral	438		438	4.4
Petroleum	31		31	
Solid waste disposal	(1,540)	(988)	(2,528)	(25.6)
Government	1,540		1,540	15.6
Residential		830	830	8.4
C-I		88	88	0.9
Industrial		70	70	0.7
Transportation		(2,181)	(2,181)	(22.1)
Gasoline		1,748	1,748	17.7
Diesel		227	227	2.3
Aircraft		176	176	1.8
Vessels		30	30	0.3
Total	3,271	6,727	9,998	100.0
% of combined	31.9	68.1	100	

important point sources of particulates in the metropolitan area are power companies, municipal incinerators, glass factories, foundries and hospitals. The spatial distribution of sources around the city and emission density isopleths are shown in Figures 13 and 14. The top 25 point sources from the inventory, accounting for 98 percent of the TSP point source emissions, are generally widespread in location and no concentration of emissions is found in any one area of the state. The most dense emissions (total emissions) are found in the CBD area where the density is 50 tons per year per square mile. This is considered a low emission density which does not by itself cause the air quality to be in violation of standards.

More specific emissions information for these sources and their compliance status is given in Table 3 (as obtained from the Compliance Data System). It was indicated that most sources in the state are in compliance except for foundries outside of the metropolitan area. Also in Table 3 is the aggregate emission estimate for each plant from the 1972 NEDS file (from which Table 1 was prepared) to compare with the Agency inventory. Several discrepancies exist from which one may conclude that the Agency inventory is more current and should be used in further analysis.

Seven of the 25 major fuel-burning sources are not in compliance or are of unknown status. While this may seem a substantial number, the impact on the monitoring network is probably minor. More important, as seen in Table 2, are TSP emissions from area fuel combustion which are more than twice as large as emissions from point source fuel combustion. Fuel combustion appears to contribute substantially to TSP concentrations and this is shown by the results of the particle characterisation study.

There are no reliable figures on historical emissions but it is believed that a downward trend in emissions has been occurring over the past 4 years. Enforcement of the particulate air pollution regulations is felt

Table 3. METROPOLITAN PROVIDENCE EMISSIONS FROM FUEL BURNING (TPY) TOP 98 PERCENT

	Type of industry	TPY	Percent total	Cumulative	MBTU emissions	Compliance status
1.	Power Generation	703	26	26	156	In compliance
2.	Municipal Incinerator	515	37	63		Installing wet scrubber
3.	Glassware	383	13	77	177	Boilers burning natural gas - in compliance Others - unknown
4.	Municipal Incinerator	257	9	86	940	In compliance
5.	Foundry	101	4	90	53	Not in compliance
6.	Rubber	101	4	94	0	Burners in compliance Mills and grinding - unknown
7.	Hospital	151	6	76		In compliance
8.	Hospital	115	4	80	5	Incinerator - unknown
9.	Building Paper & Board	99	3	83	99	In compliance
10.	Oil Storage	93	3	86	191	Basically in compliance (crude - pipe)
11.	Brewery	97	3	89	141	Basically in compliance
12.	Power Generation	61	2	91	309	#6, #2 - unknown Most in compliance
13.	Metal Fabrication	66	3	93	99	In compliance for ?
14.	Power Generation	62	3	96		
15.	University	58	3	95	86	In compliance Miner - unknown
16.	Foundry	58	3	91	88	Boilers - in compliance
17.	Construction	37	3	96		
18.	Power Generation	83	3	97		In compliance
19.	Foundry	30	3	98		Not in compliance
20.	Plastics	30	3	99	19	In compliance
21.	Construction	19	3	100		
22.	Rubber	18	3	100	31	In compliance
23.	Paving & Blocks	11	3	100	19	Dryers - in compliance Mixer - not in compliance
24.	Paving & Blocks	11	3	100		Concrete mixer - not in compliance
25.	Paving & Blocks	8	3	100		One-half in compliance One-half - unknown

by the agency to have accomplished the following changes in emission levels: a 90 percent decrease in emissions from existing incinerators (three large municipal incinerators and many small ones were shut down), little change in emissions from the asphalt industry, and a 90 to 95 percent decrease in emissions from foundries since 1970. In addition, Regulation 8, which has required the use of low sulfur fuel throughout the state since March 1, 1972, is believed to have caused a significant switching in fuel usage from the expensive low-sulfur residual oil to the naturally cleaner distillate oil for economic reasons. This was noted due to the decrease in the number of smoke detectors required of residual oil users.

Other reductions in emissions are known to have occurred as a result of factors outside of air pollution control - primarily the economic and energy situations. These are important due to their currentness and also the impact that they have on the area source emissions.

The state has been experiencing an economic decline for several years which has resulted in the closing of factories, the slowing down of production, and significant increases in the unemployment rate. Of the 25 major point sources listed, four have gone out of business, two experienced strikes during 1974, and at least two others have significantly decreased production. Although not in the metropolitan area, it is worth noting that the United States Navy abandoned its Newport and Quonset Point installations in 1974, significantly decreasing the emissions in those areas.

The energy situation has contributed to changes in and the decline of fuel usage in the state, resulting in a corresponding drop in the emission of particulates. Historically, Rhode Island was first affected by the availability of energy when coal became increasingly difficult to obtain during the 1950's and 1960's and users gradually switched over to oil. The power company in Providence, the largest source of particulates in the state, was the last to change, in 1967. Thereafter, a

noticeable improvement in air quality was recorded at the Providence NASN site (site 52, Providence Police Station) and was attributed to this last change.

More recently, it is estimated that a 15 percent reduction in residential fuel burning and a 20 percent reduction for commercial and institutional uses occurred between 1973 and 1974. Actual fuel usage data for the years 1971 to 1973 are given in Table 6. A continuing reduction in fuel usage and total energy consumption is apparent. The use of residual oil decreased most markedly from 1971 to 1973, with an 18 percent reduction from 1971, the year before low sulfur oil was required. During the same time, however, the use of distillate oil did not increase but decreased 5 percent. The overall reduction in fuel usage is expected to relate not only to the emissions from point sources but also those from area sources. As shown in Table 5, residential space-heating and commercial boilers and furnaces account for 74 percent of the petroleum consumed in the state for nontransportation purposes.

Although the decrease in fuel consumption since 1971 appears well documented, there is no corresponding improvement in air quality. This may be due, in part, to changing meteorological factors.

The regulations, shown in Table 13 with their effective dates, are broadly and simply stated. The important sources of TSP, which seem to be fuel oil combustion and fugitive dust, do not appear to be specifically addressed by the regulations. Though there are a visible emissions regulation and a regulation requiring the use of smoke detectors on all residual burners, other regulations on fuel oil combustion could be adopted for residential and small commercial boilers if the need arose.

Incinerator related emissions are now primarily from municipal incineration, due to the adoption in 1974 of a regulation requiring multiple chamber incinerators. More rigorous enforcement could be applied and small incinerators could be banned if necessary in the future, although most are now closed.

Table 4. FUEL CONSUMPTION BY FUEL TYPE AND YEAR

	1971	1972	1973	1974	Conversion factor to billion Btu
Oil (1000 bbl)					
distillate	9,070	9,176	8,633		5,825
residual	10,236	9,811	8,376		6,287
gasoline	9,333	9,555	9,694		5,248
other	1,354	2,052	2,052		5,248
Coal	0	0	0		2,396
Natural gas (mcf)	25,638	22,470	21,343		1,032
Hydroelectric (kWh)	0	0	4		1,038
Nuclear (kWh)	0	0	0		1,803
Btu from distillate and residual	117,186	114,360	102,947		
Total (Btu)	199,458	198,839	186,269		

Table 5. RHODE ISLAND FUEL CONSUMPTION BY CONSUMER TYPE 1973

	Petroleum, 1000 bbl	Natural gas, mcf
Household commercial	12981	17354
Industrial	1874	3973
Transportation	12958	16
Electric power	2707	148
Miscellaneous	73	0
Total	30594	21491

Source: Fuel and Energy Data, USDI Bureau of Mines.

The effect of urban and traffic related dust is apparent at the Dyer Street site from the high TSP concentrations and the results of the particle characterization study. A control strategy for urban dust does not exist. The dust reentrainment problem in Providence is presently lessened by the frequent rainfall and the associated cleansing of street.

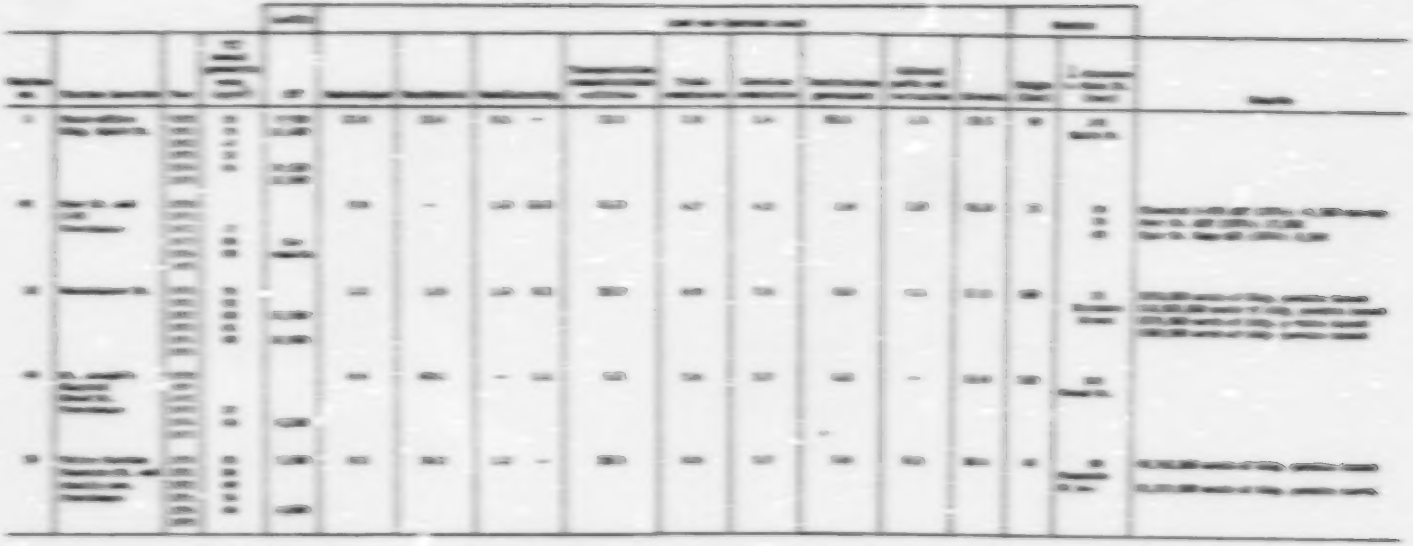
Urban Activity Factors

Land Use and Traffic Activity - The City of Providence Department of Planning and Urban Development provided land use maps for areas surrounding monitor sites numbered 1, 12, 42, 49 and 52. The percent land area devoted to each of nine land use categories within a 1000 foot radius of each monitoring site was determined and is shown in Table 6.

Figure 8 shows the relationship between percent residential, undeveloped, cultural, parks and recreational land use activities and 1974 TSP levels (visually fitted). The following observations were made:

- TSP concentrations show an apparent decrease as the percent residential, undeveloped land, etc. (as opposed to manufacturing, commercial, streets, etc.) increases.
- Site number 42 has more manufacturing (17 percent) and streets (41 percent) than any of the other four sites. Activities associated with these land uses are relatively dirty. This together with a relatively low monitor height (15 feet above ground) and heavy traffic volumes from Rt. I-195, Dyer St. and Dyer St. Ramp contributes to higher than expected TSP concentrations.
- The remaining four points fit the linear relationship rather consistently. Variations among these four sites could be explained by monitor heights, distances to nearby major streets and traffic volumes on those streets.

Table 6. [illegible]



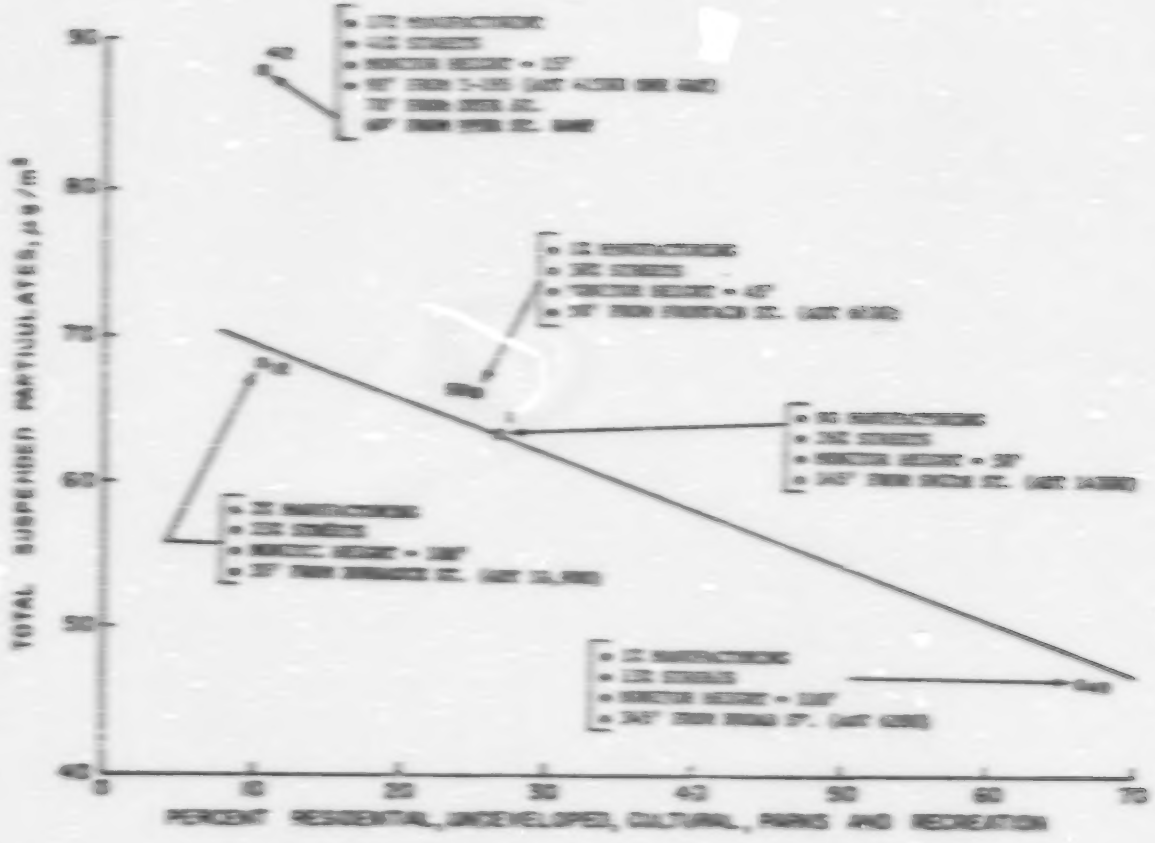


Figure 8. Relationship of TSP and types of land use

Figure 9 illustrates the relationship between ADT per slant distance and 1974 TSP concentrations. ADT per slant distance is a measure used to combine the effects of traffic volume, perpendicular distance to the nearest major street, and above ground monitor height. It appears that TSP concentrations increase as the ADT per slant distance increases. All four points fit the linear relationship consistently. The Dyer Street site was not included in this figure because it is an anomaly with respect to traffic volume due to its proximity to an expressway and an entrance ramp.

While Figure 9 clearly indicates that TSP concentrations are strongly correlated to traffic volume for a given slant distance, this cannot be necessarily accepted as a strictly causative relationship. Comparison of the somewhat limited data on trends in ADT at five downtown sites (Table 6) with the year-to-year trends in TSP concentrations shows no obvious relationship, confirming that ADT cannot be construed as a precise quantitative predictor of particulate concentrations. Rather, since other land use factors also have strong relationships to TSP concentrations, as in Figure 8, it is more accurate simply to consider ADT as a very good indicator of the overall aggregate human activity that contributes to an urban level of suspended particulate.

Construction Activity - Since construction activity was noted in the vicinity of several of the monitoring sites during the past few years, a compilation was made of data on the amount of construction as measured in various ways. Table 7 records the number and value of building permits for 1971 to 1974. The number of building permits issued has steadily increased from 1971 to 1974 and the total value of construction increased from 1971 to 1973 but decreased in 1974 almost to the 1971 value. TSP concentrations at the center city sites, however, have not consistently followed either of the above trends, being relatively high in 1971, decreasing in 1972 and 1973, and increasing slightly in 1974. Thus it is not possible to confirm a definite relationship between citywide construction activity and TSP concentrations on a macro scale.

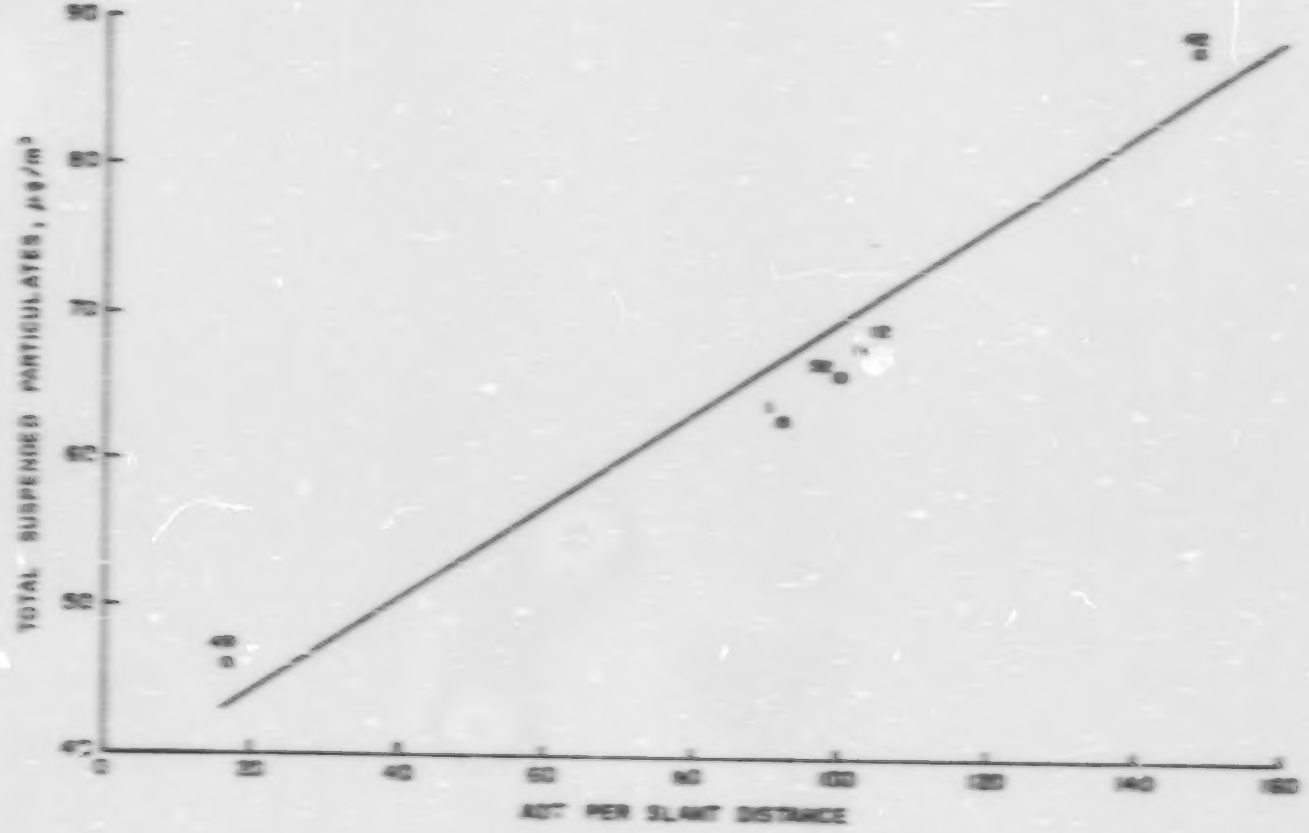


Figure 9. Relationship of TSP and traffic counts (ADT) per slant distance

It seems, however, to be far more useful to examine TSP concentrations in relation to specific construction projects, with due consideration to the scale of the project and to the proximity of that project to a particular monitoring site. In recent years, two monitoring sites in downtown Providence have had major construction projects completed nearby.

Table 7. PROVIDENCE BUILDING PERMITS

Permit classification	Number of permits			
	FY 1971	FY 1972	FY 1973	FY 1974
New buildings	90	176	284	138
Additions and alterations	725	824	774	1,092
Razing dilapidated buildings	346	421	408	371
Other	287	218	187	217
Total	1,448	1,639	1,653	1,818
	Value of construction			
New buildings	$11,095,200	$20,768,500	$19,717,900	$10,284,700
Other	1,927,500	3,739,750	5,405,600	7,900,800
Total	$13,022,700	$24,508,250	$25,123,500	$18,185,600

In the vicinity of site number 9I (Police Station at Fountain St. and Atwells Ave.) building permits were issued in fiscal year 1971 for a new Civic Center ($7,542,000) and for a 120 unit apartment building at 210 Fountain St. ($1,220,300). Both facilities are approximately 600 feet from the monitor location. In the vicinity of site number 12 (Westminster St.) a building permit was issued in fiscal year 1972 for a new Rhode Island Hospital Trust Building at 40 Westminster St. ($9,550,000), some 200 feet from the monitor location.

During the time when excavation and heavy exterior construction was being conducted, relatively high TSP readings were observed. At site 52, for example, annual geometric mean TSP concentrations of 85 and 84 $\mu g/m^3$ were recorded in 1970 and 1971 respectively. In 1972, 1973 and 1974, annual geometric mean TSP concentrations decreased to 69, 54, and 66 $\mu g/m^3$ respectively. Similarly, at site 12, annual geometric mean TSP concentrations increased from 56 $\mu g/m^3$ in 1970 to 92 $\mu g/m^3$ in 1971. (Part of the substantial decline is probably due to the decrease in rainfall between the 2 years which was discussed previously.) Since 1971, when much of the heavy construction for the Rhode Island Hospital Trust Building was accomplished, TSP concentrations returned to more typical levels of 68, 61 and 68 $\mu g/m^3$ in the next 3 years to 1974.

The clear implication of these observations is that heavy construction activity, excavation and building frame erection can have a significant effect on TSP concentrations at specific monitoring sites, even though there may not be an overall direct relationship between citywide construction activity and TSP concentrations at all monitoring sites citywide. Table 8 shows the potential magnitude of this effect.

Monitoring Network Evaluation

The geographical configuration of the Rhode Island hi-vol network is adequate for the air quality in the state. Sampling sites are located throughout the state and represent the wide variety of land development present in the area. Coastal areas are represented by sites in Narragansett and Newport (No. 50 and No. 7), undeveloped areas by the site in Exeter (No. 54), a wide variety of suburban areas by Burrillville, Woonsocket, Bristol, Tiverton, Cranston, Warwick, Westerly, and East Providence (Nos. 3, 4, 5, 6, 8, 9, 10, 46, 47, and 48), and center city areas by Providence, Pawtucket, and East Providence (Nos. 1, 2, 12, 42, 52, and 53). Industry is widespread in location and there is no area with a substantial concentration of heavy industry, so the lack of a specifically industrial monitoring site is appropriate.

Table 8. BUILDING CONSTRUCTION AND TSP LEVELS AT SITES 52 AND 12

Year	Permits issued	Construction: Project	Construction: Value	Proximity to nearest station (m)	Nearest height (m)	TSP levels ($\mu g/m^3$): During construction	TSP levels ($\mu g/m^3$): After construction (1976)	Difference
52	FY 1971	New Civic Ar.	$1,347,000	400 ±	45	91 (1970)	66	25
	FY 1971	Apts. at 220 Fremont St.	$1,120,000	400 ±				
12	FY 1971	40 Financial Tower Building, 40 Embarcadero	$4,130,000	200 ±	100	92 (1971)	68	24

In general, the specific siting of the hi-vols is also adequate, although three of the Providence CBD sites are worthy of specific note. The State Office Building site (No. 1) is relatively high and in an area somewhat more open than would be typically considered Central Business District. The Westminster Street site (No. 12) is also high, and somewhat surrounded by even taller buildings. It is not badly sited in the traditional context of large point source emissions, particularly in light of the normal difficulty in finding adequate sites in CBD areas; however, in the context of the greater significance of area sources and urban fugitive dust seen in Providence, it is probably too well screened from the adjacent streets to be considered a typical CBD site.

The third site of special concern is the Dyer Street site (No. 42). It is located in the open area within the Dyer Street interchange, completely surrounded by the I-95 expressway, Dyer Street, and the access ramp. Though originally placed to monitor the potential effect of the nearby power plant, it is also clearly influenced by the adjacent traffic. Originally on the ground, and since August 1974 on top of a trailer (at 15 feet), it is actually below the level of the expressway roadbed, which is elevated at that point. It is true that careful analysis of data from the Dyer Street site, in conjunction with meteorological data, etc., would provide quite useful information with respect to the impact of both the power plant and the nearby traffic concentration.

Aside from these minor concerns about siting in a few cases, the principal overall feature of the network is the general height of the hi-vols. As seen in Table 14, only 10 of the 27 sites listed are 20 feet or less, and two are at 100 feet. It is generally recognized, although not so quantitatively documented as would be desirable, that measured particulate levels decrease significantly with height above the ground. Present EPA policy concerning standardization of monitoring heights is considered interim, pending research on the issue, so that it is not possible to define the degree to which any network is good or bad, better or worse, with respect to the issue of hi-vol height. The present EPA guidance

considers appropriate any height up to 50 feet; in this perspective, only three of the 27 Rhode Island sites are too high, which is certainly not excessive in the context of monitoring throughout the country. On the other hand, within the limitation of 50 feet, the number of sites (9 of 21) that are in the range 45 to 50 feet high is much greater than is typical of urban monitoring networks.

SECTION III

SUPPLEMENTARY INFORMATION

NATURE OF THE AREA

Topography and Climatology

Narragansett Bay is the most prominent topographic feature of the region, providing extensive shoreline and dividing the population centers. The AQCR contains two distinct physiographic provinces — hilly New England upland, covering the northwestern third of Rhode Island, and seaboard lowland, a narrow strip of rolling land that borders the coast. After an abrupt rise of 200 feet just west of Narragansett Bay, the land surface rises gradually northwest to a plateau having an elevation of about 600 to 700 feet. The topography is such as to have a more beneficial than deleterious impact on air quality in the region.

There is generally good ventilation by air masses having low background particulate levels, and the proximity to Narragansett Bay and the Atlantic Ocean plays an important role in determining the climate for Providence and vicinity. In the summer, onshore flow results from the routine occurrence of daytime seabreezes under light gradient wind conditions. In the winter, prevailing winds are from the west to northwest, and the frequent passage of cold fronts and coastal storms introduces fresh, continental polar air into the area.

Measurable precipitation occurs frequently, about 1 day out of every 3, and is fairly evenly distributed throughout the year, with only slightly

more during the winter months. The annual average is a little more than 40 inches, but the past 5 years have averaged over 47 inches with a high of 65 inches in 1972, see Figure 4. The first snowfall of winter usually comes toward the end of November, with the last about the middle of March. However, the Bay and the Atlantic Ocean help to moderate temperatures, and many of the major winter storms drop their precipitation in the form of rain rather than snow. The average total snowfall for the winter season is about 38 inches, though the past five winters have averaged only 31 inches, ranging from 45 inches in the 1969 to 1970 season to 11.3 inches for the winter of 1972 to 1973.

The temperature for the entire year averages about 50 degrees F and there are an average of almost 6,000 heating degree-days. The coldest months are usually January and February, with mean temperatures near 29 degrees F and heating degree-days of 1,135 and 997, per month, respectively; the warmest months are July and August, with mean temperatures around 72 degrees F. The past five winter seasons have seen a slight decline in the winter heating load in each year, from 6,330 degree-days during 1969 to 1970, to 5,359 during 1973 to 1974.

Stagnating meteorological conditions of relatively short duration occasionally occur in the fall and winter seasons. However, Holsworth's calculations of annual normalized pollutant concentrations for the contiguous U.S., assuming a standard city size of 10 km and based on mixing heights and average wind speeds, indicate that Providence is among the most favorably located cities in the country with respect to pollution potential. Some transport of particulates into the region seems to occur when air masses associated with the Bermuda High sweep up along the east coast and through the state. Otherwise, due to the proximity of the bay and ocean and the generally undeveloped area in the direction of prevailing winds, particulate transport is probably minimal.

Land Use, Employment, and Population Patterns

The Metropolitan Providence Interstate Air Quality Control Region has three major centers of urban activity -- Providence, Rhode Island and Fall River and New Bedford, Massachusetts -- shown in Figure 10. This broad urban area is centrally located in the AQCR, encompassing most of eastern Rhode Island, as well as the areas in Massachusetts bordering the Atlantic coast and the State of Rhode Island. Much of western Rhode Island is nonurban, and in Massachusetts the band of communities north of Fall River, from Mansfield east to Plymouth, remains only moderately developed.

Rhode Island is the second most densely populated state in the nation (after New Jersey) with an average of 905 persons per square mile. Table 9 indicates the geographic distribution of the state's population. Within the metropolitan area, manufacturing activity is well dispersed, and there are no coherent industrial areas.

Data describing employment changes and employment by major industry groups are presented in Tables 10 and 11. Major industries in Rhode Island include the manufacture of jewelry and silverware, primary metal processing, metal products, machinery, rubber and plastics, food processing, chemicals, and apparel. The tourist industry is also a significant factor in Rhode Island's economy.

Automobile usage in Rhode Island is described in Table 12. In 1973, 73 percent of the vehicle miles traveled in the state were in the Providence-Warwick-Pawtucket SMSA. The total amount of roadway mileage in the state has increased from 4,900 miles in 1968 to 5,470 in 1972. More than 80 percent of these roadway miles are in the urban area and more than 95 percent are paved.

Figure 10. Map of AQCR

Table 9. GEOGRAPHIC DISTRIBUTION OF RHODE ISLAND POPULATION

County	Land area, sq mi	1970 Population	1970 Population density
Bristol	24.9	45,937	1,845
Kent	172.5	142,382	825
Newport	104.9	94,228	898
Providence	415.5	581,470	1,399
Washington	331.2	85,706	259
State	1,049.0	949,723	905
SMSA	613.9	769,789	1,256
City of Providence	18.9	173,000	9,153

Source: 1975 World Almanac

Table 10. LABOR FORCE AND EMPLOYMENT

Year	Labor force	Number unemployed	Unemployment ratio, %
1970	396,600	20,500	5.2
1974	427,800	31,500	7.4
1975[a]	451,000	62,700	13.9

[a]Average for first three months.

Source: Rhode Island Statewide Planning Program, State Land Use Policies and Plan, draft (Jan. 1973), revised Nov. 1974.

Federal Reserve Bank of Boston, New England Economic Indicators, May, 1975

Table 11. EMPLOYMENT BY MAJOR INDUSTRY GROUP[a] (Providence - Warwick - Pawtucket SMSA)

Industry Group	Number Employed (1972)[b]	Percent
Agricultural Services Forestry, Fisheries	453	0.2
Mining	189	0.1
Contract Construction	11,105	4.2
Manufacturing	110,469	42.0
Transportation, Public Utilities	13,984	5.2
Wholesale Trade	16,584	6.2
Retail Trade	45,278	17.1
Finance, Insurance, Real Estate	16,351	6.2
Services	47,613	18.1
Unclassified	1,395	0.5
Total	262,740	100.0

[a]Only those employees covered by the Rhode Island Employment Security Act.

[b]Excludes government employees, railroad employees, self employed persons, farm workers and domestic service workers. Those workers excluded comprise 24.8 percent of the total labor force.

Source: U.S. Department of Commerce Social and Economic Statistics Administration, Bureau of the Census, County Business Patterns Rhode Island 1972.

Table 12. AUTOMOBILE USE IN RHODE ISLAND

	1970	1973
Population	950,000	973,000
No. Private Autos Registered	433,000	479,000
Persons per Private Auto	2.20	2.04
Total Vehicles Registered (trucks, buses, etc.)	488,000	563,000
Licensed Drivers	511,000	448,000
Vehicle Miles Traveled	12,351,000[a]	13,941,000

[a]1969 Estimate.

Sources: World Almanac 1975

Arthur D. Little, Historical Data on New England's Energy Requirements. Prepared for the New England Regional Commission, September 1974.

R.I. Statewide Planning Program, State Land Use Policies and Plan, November 1974.

GCA/Technology Division Development and Evaluation of a Transportation Control Plan for Rhode Island. Prepared for U.S. Environmental Protection Agency, May 1973.

LEGAL AUTHORITY, REGULATIONS AND SURVEILLANCE

Under the 1966 Rhode Island Clean Air Act, the Rhode Island State Department of Health is designated as the state air pollution control agency "for all purposes of any federal air pollution control laws, acts, or programs..." The Division of Air Pollution Control, within the health department, is the administering agency for all rules and regulations for the prevention and control of air pollution throughout the state as there are no local air pollution control agencies.

There are 14 regulations, promulgated under this act, relating to the problem of air pollution control in the state, ranging from the control of visible emissions and open fires to the control of emissions from specific sources (see Table 13). Most of these regulations are quite simply stated and could, in some cases, be interpreted to give broad

Table 13. RULES AND REGULATIONS FOR THE PREVENTION, CONTROL, AND ABATEMENT AND LIMITATION OF AIR POLLUTION, STATE OF RHODE ISLAND

Regulation	Effective date
1. Visible Emissions	2 August 1967[a]
2. Handfiring of Soft Coal	2 August 1967
3. Particulate Emissions	2 August 1967[a]
4. Open Fires	2 August 1967[b]
5. Preventing Particulate Matter From Becoming Air-Borne	2 August 1967
6. Air Contaminant Detectors	2 August 1967
7. Emission of Air Contaminants Detrimental to Person or Property	2 August 1967
8. Limiting Sulfur Content of Fuels	1 October 1971
9. Prior Approval by the Director of Health of Plans Relative to the Construction, Installation or Modification of any Machine, Equipment, Device, Article or Facility Capable of Becoming a Source of Air Pollution, or any Air Pollution Control System	3 October 1971[c]
10. Air Pollution Episode Regulations	28 February 1972
11. Control of Nitrogen Oxides Emissions From Gas-Fired and Oil-Fired Fuel Burning Equipment	28 February 1972
12. Prevention and Control of Air Pollution From Incinerators	28 February 1972[d]
13. Prevention and Control of Air Pollution From Fuel Burning Equipment	17 January 1973
14. Record Keeping and Reporting	14 May 1973

[a]Amended 28 February 1972

[b]Amended 1 October 1971

[c]Amended 17 January 1973

[d]Amended 25 February 1973

powers to the control agency. Those regulations pertaining directly to particulate emissions are summarized below:

Regulation 1 - prohibits the discharge, for more than a total of 3 minutes in any 1 hour, emissions "as dark or darker than that shade designated No. 1 on the Ringelmann Chart."

Regulation 2 - prohibits the sale of any solid fuel except coke and anthracite; requires the use of approved mechanical fuel-burning equipment for coal with a dry basis volatile content greater than that of anthracite and allows such fuel to be used if it meets the anthracite smoke production standards.

Regulation 3 - sets a particulate emission rate for all sources based on process weight rate using the total process weight except for liquid and gaseous fuels (see Figure 11).

Regulation 4 - prohibits open fires for refuse disposal.

Regulation 5 - requires the use of "reasonable precautions" to prevent particulate matter from becoming airborne.

Regulation 6 - requires the use of smoke detectors for all power plants burning residual oil and all plants of 1 million Btu/hr capacity or over burning solid fuel.

Regulation 7 - prohibits emissions which may obscure visibility or which "in any way interferes with the enjoyment of life and property."

Regulation 8 - requires the use of multiple chamber incinerators after January 31, 1974, and sets maximum 2-hour average emission levels of 0.08 gr/scf (0.18 g/Nm^3) from incinerators with an input capacity greater than 2,000 pounds per hour and 0.08 or 0.16 gr/scf for smaller incinerators depending upon the type of refuse burned.

Regulation 11- prohibits the emission of particulate matter from fuel-burning equipment at a rate greater than 0.20 pounds per million Btu per hour heat input for heat inputs of 1 million to 250 million Btu per hour and at a rate greater than 0.10 pounds/10^6 Btu/hr for larger inputs.

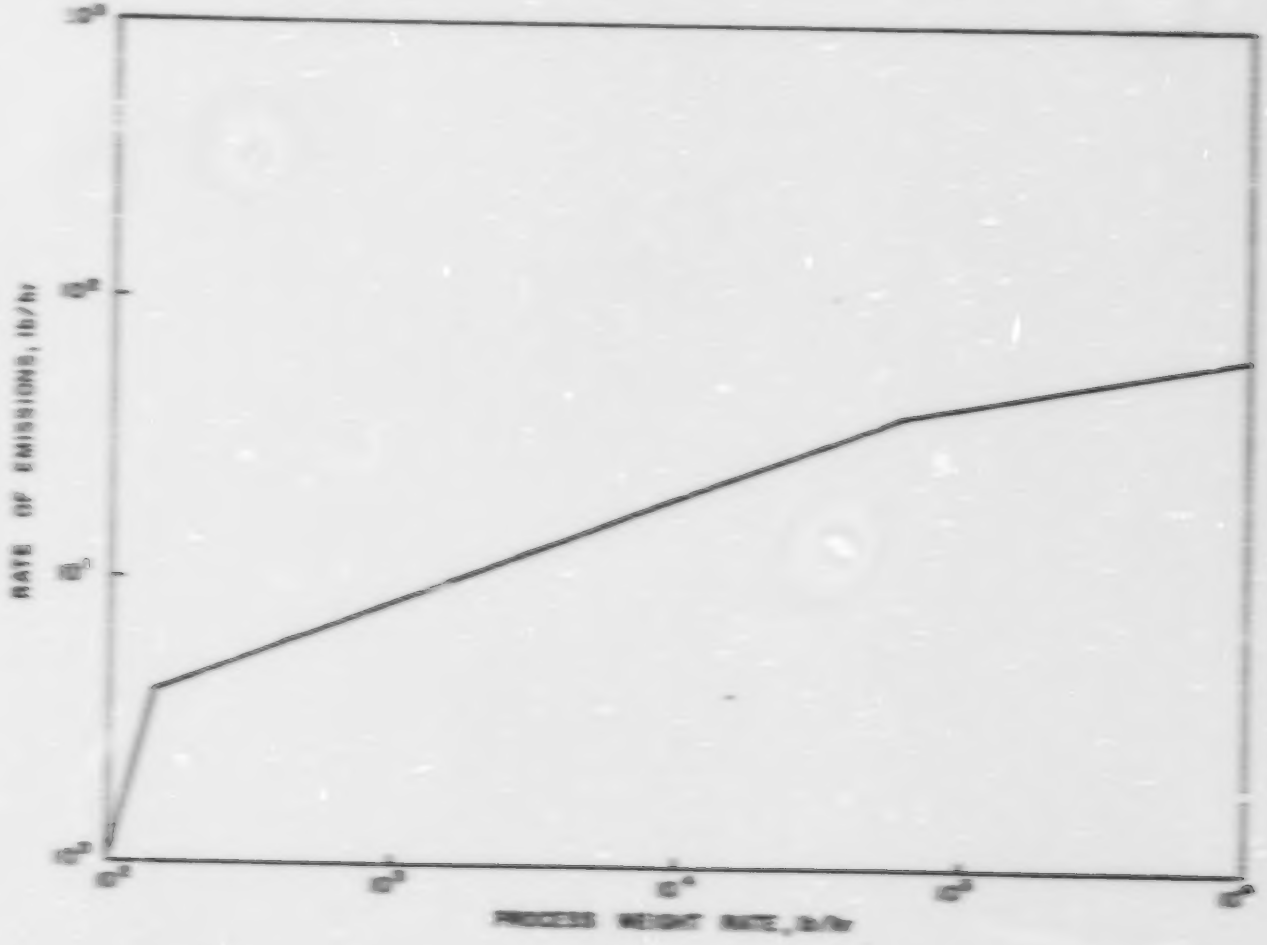


Figure 11. Process weight regulations curve

In addition to these regulations which are particulate emission oriented, the reduction in the sulfur content of fuel, as required by Regulation 9, is expected to decrease the total particulate emission due to both simply burning a cleaner fuel and encouraging users to switch to distillate from residual oil.

Actual stack testing of major sources occurs infrequently, once every couple of years at most, and is usually performed by consultants hired by the source being tested. The determination of compliance and estimates of emissions are made by noting the type of controls a source has installed and assuming that the controls are being operated continuously and adequately.

Any ongoing surveillance of sources is through the use of the opacity regulation. Sources are generally felt to be in compliance with existing regulations except for foundries outside of the metropolitan area.

EMISSIONS

The locations and emissions of major point sources in the Providence metropolitan area are shown in Figure 13. It can be seen that point sources tend to be widespread in location and that there is no one area where industry is concentrated.

Isopleths of total emissions density are shown in Figure 13 for the state. The density of emissions is concentric around the metropolitan area and follows the pattern of suburban development. In general, the emissions density is low, with only a small central area with a density of 50 TPY per square mile.

NETWORK DESIGN AND MONITOR SITING

Information about each sampling site in the network is given in Table 14, which includes the site location, the local and SAROAD code numbers, the

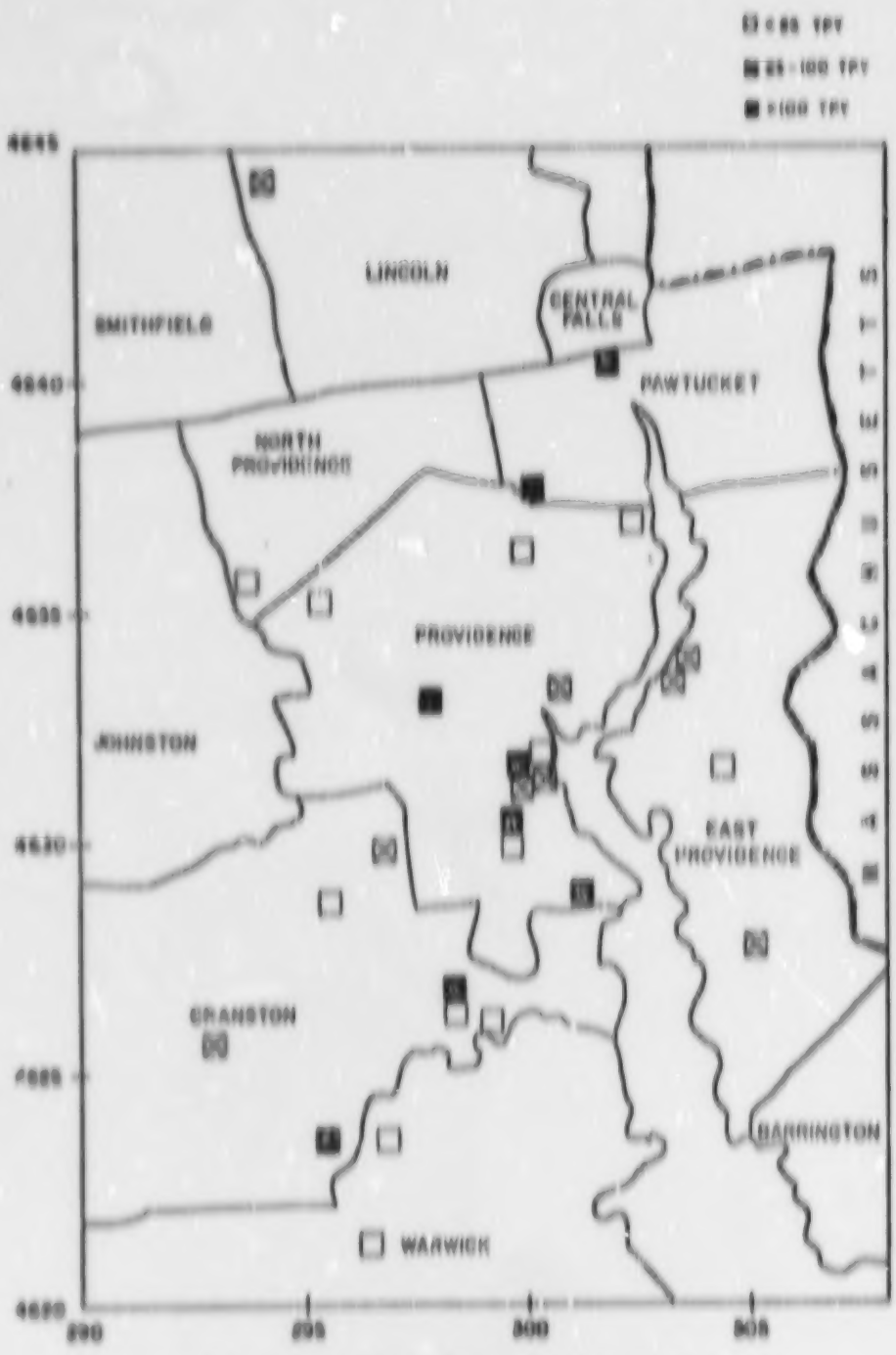


Figure 12. Locations of point sources

Figure 13. Emissions density isopleths. TPY/square mile

Table 14. [redacted]

[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

height of the monitor, the characteristics of the neighborhood, and the active dates. The locations of the sampling sites are shown for the state in Figure 14 and for the metropolitan area in Figure 15.

Eight of the sampling sites in the metropolitan area were visited in order to make assessments of the hi-vol exposure and other siting criteria, and to evaluate any possible impacts of each site's immediate neighborhood on the TSP values recorded there. The resulting information about these eight sites is presented below and summarized in 14, including for each of the local sources.

State Office Building

This site (No. 1) is located in a built-up area surrounded by parking lots and roads, on top of a hill 3/4 of a mile from and 70 feet higher than the central business district. Interstate 95 is 1/4 of a mile to the east. The monitor receives good ventilation and good exposure.

Westminster Street

The monitoring site on Westminster Street (site No. 12) is located on the roof of a five-story building in the central business district. There are taller buildings across the streets to the north and east. Nearby sources are the heavy traffic on the streets around the building, nearby building furnaces, and the electric power plant 1 mile away. A great deal of construction has also occurred nearby within the past 5 years.

Dyer Street

The monitoring site on Dyer Street (site No. 42) is located on the roof of a trailer set in the cloverleaf between an entrance ramp and Interstate 195, both heavily traveled by motor vehicles. The site is in the commercial area of the center city, 1/4 of a mile northwest of the power company. The site is only about 60 feet horizontally distant from the highway, and just slightly below the level of the pavement, which is elevated.

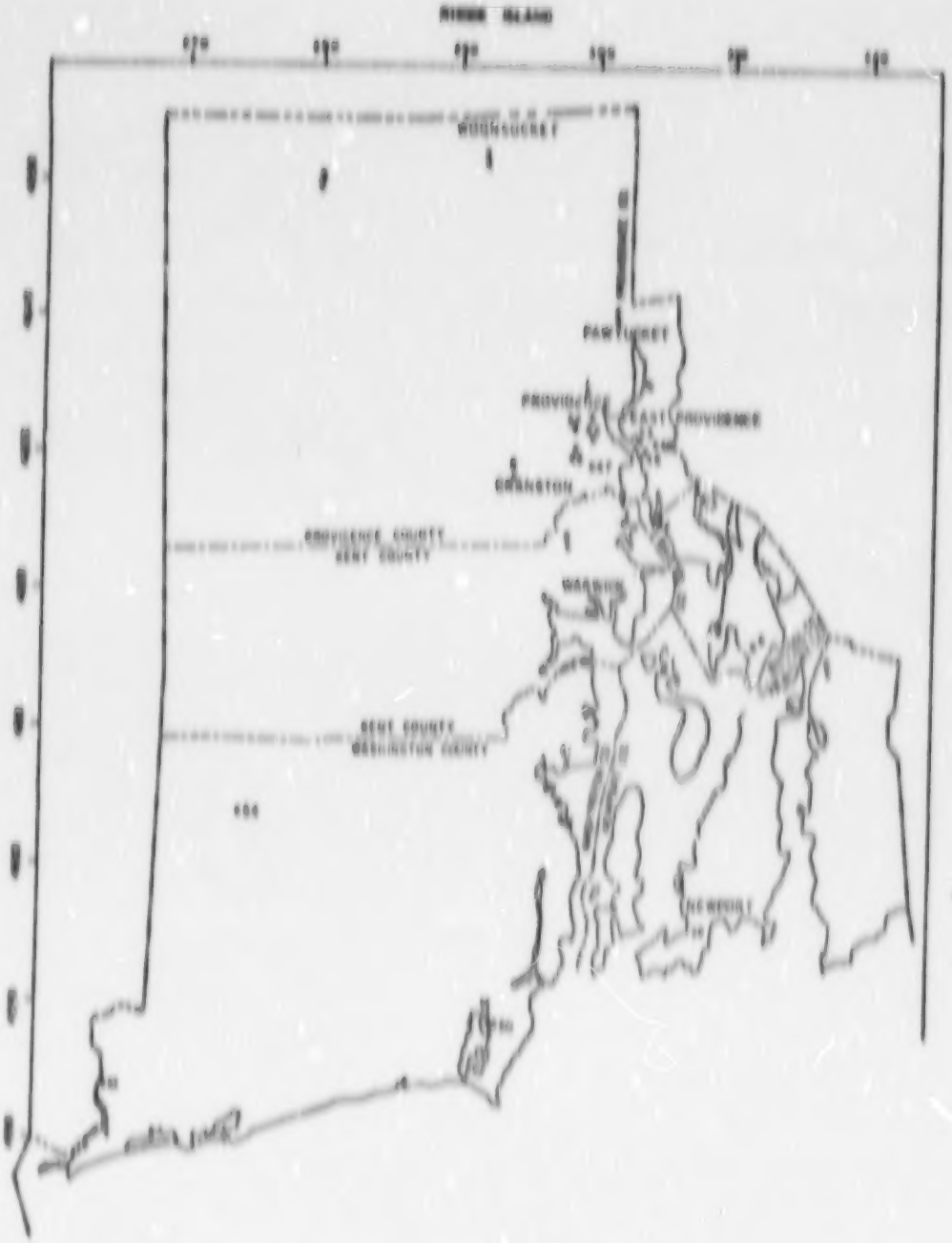


Figure 14. Location of sampling sites in Rhode Island

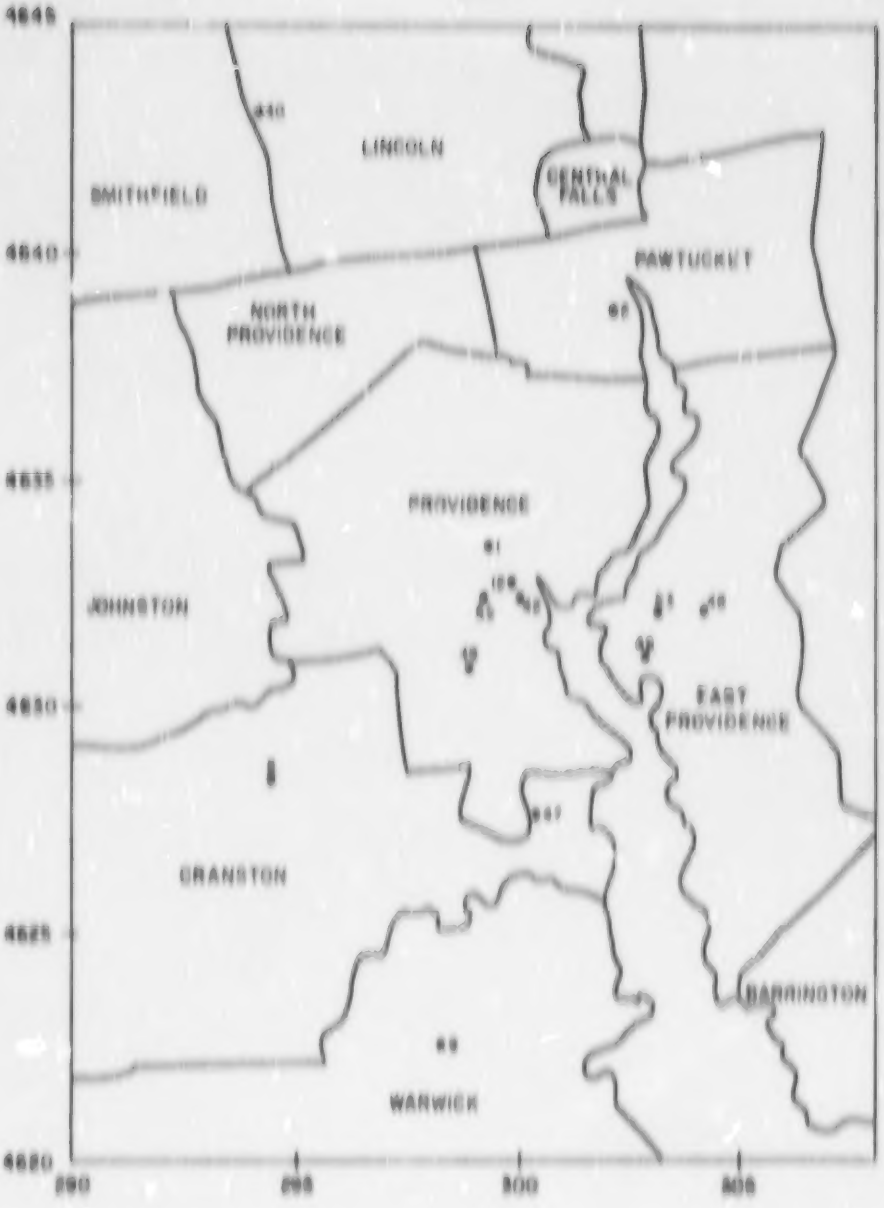


Figure 15. Location of sampling sites in Providence metropolitan area

The Providence Police Station

This site (site No. 52) is in a commercial area of the center city, 1/8 of a mile east of Interstate 95. Traffic is heavy on the surrounding streets. The nearby land use is characterized by a high proportion of streets and parking along with residential, commercial, institutional, government and cultural buildings. A boiler stack 30 feet from the monitor is a possible local source. Two large construction projects in the immediate vicinity were completed in 1971 and others have occurred or are occurring more recently.

The Central Junior High School

Site No. 53 is in a suburban residential and commercial area of East Providence. Traffic on the surrounding streets is heavy. The monitor is on the roof of a three-story building.

The Tristam Burgess School in East Providence

Site No. 46 is on the roof of a two-story elementary school in a suburban residential area, with homes and a golf course nearby, less than 2 miles east of the industrial area in Providence. The streets are curbless and traffic is medium.

The Cranston General Hospital

Site No. 47 is located in a suburban residential area which is well covered by lawns, trees, and shrubs. It is on the roof of a three-story hospital building, and is generally well exposed. The Bay lies to the east southeast, with dense residential and some commercial and industrial development from the southwest to west.

St. Joseph's Hospital

Site No. 49 is also located in a suburban residential area, with land use in the vicinity predominantly residential. Ventilation and exposure for the monitor, which is seven stories high, is quite good.

AIR QUALITY TRENDS

Suspended particulates are currently monitored at 21 sites in the state. The three NASN sites have been operated for the longest period of time -- the particulates trends at these sites have already been discussed. The particulate sampling network in Rhode Island was expanded after 1968 allowing for more representative monitoring of air quality levels. Since then, the trends at most of the stations have indicated that the concentration of TSP has been fairly constant. Available data over the past 5 years for all sampling sites in the state are presented in Figures 16 through 21, grouped according to geographic areas. The levels for the sites in a particular area tend to be close and to vary similarly. Most sites throughout the state showed a significant increase in TSP levels in 1971, followed by a decrease in 1972. In addition, a small increase is frequently noted in 1974.

REFERENCES

1. U.S. Environmental Protection Agency. Monitoring and Air Quality Trends Report. 1972.

2. Lillis, E. J., Sr., and T. G. Pace. The National Status of Air Pollution by Total Suspended Particulates and Future Prospects for Control. Presented at the annual meeting of the Air Pollution Control Association, Boston, Massachusetts. June 15 to 20, 1975.

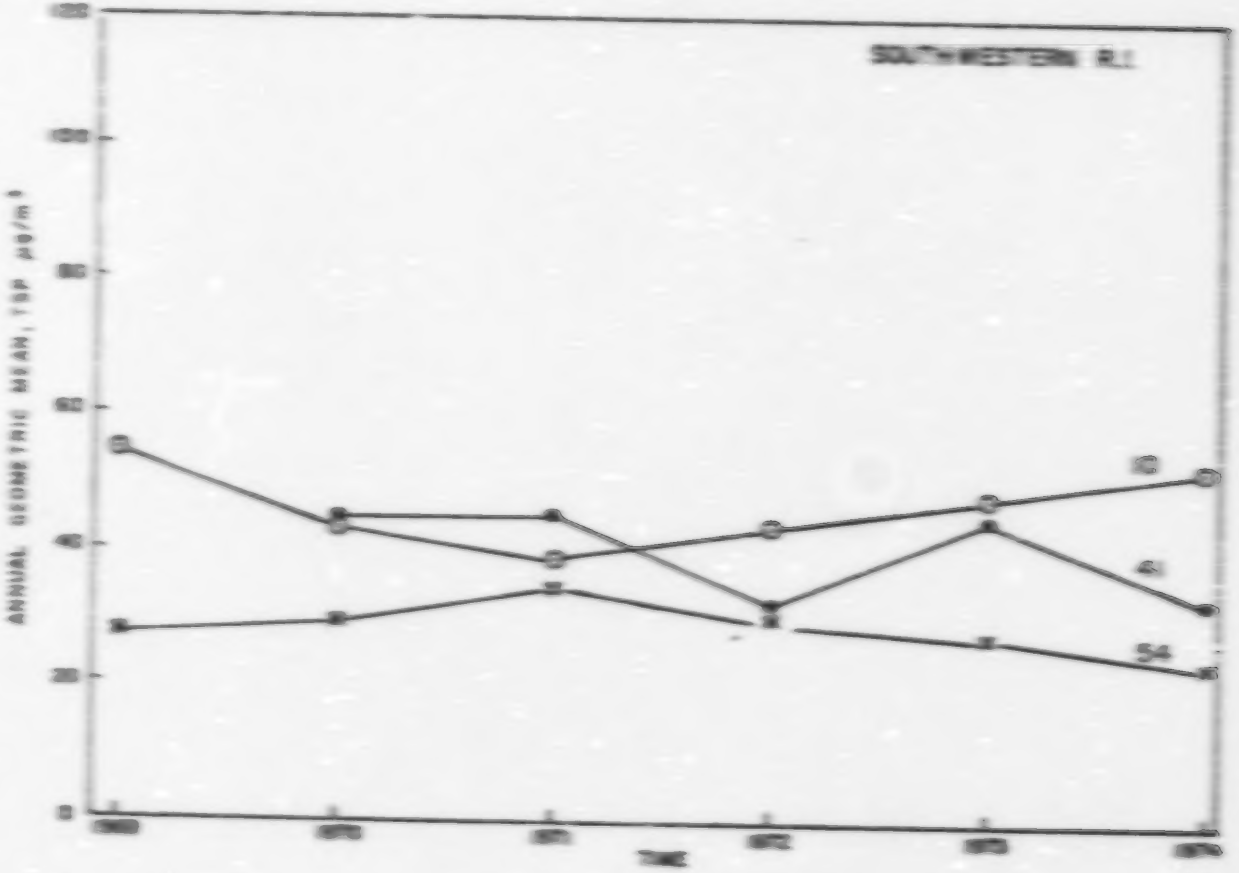


Figure 16. Annual geometric TSP means for southwestern Rhode Island

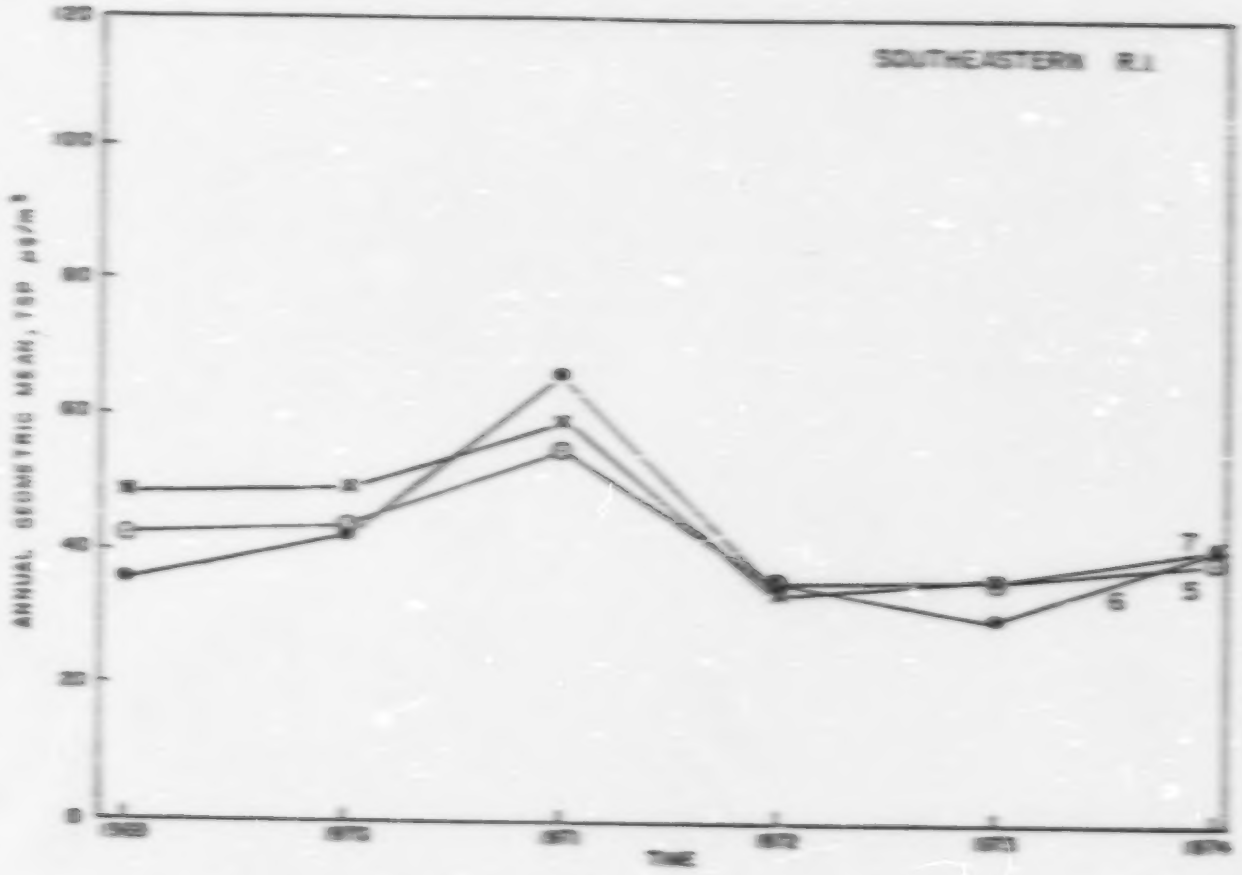


Figure 17. Annual geometric TSP means for southeastern Rhode Island

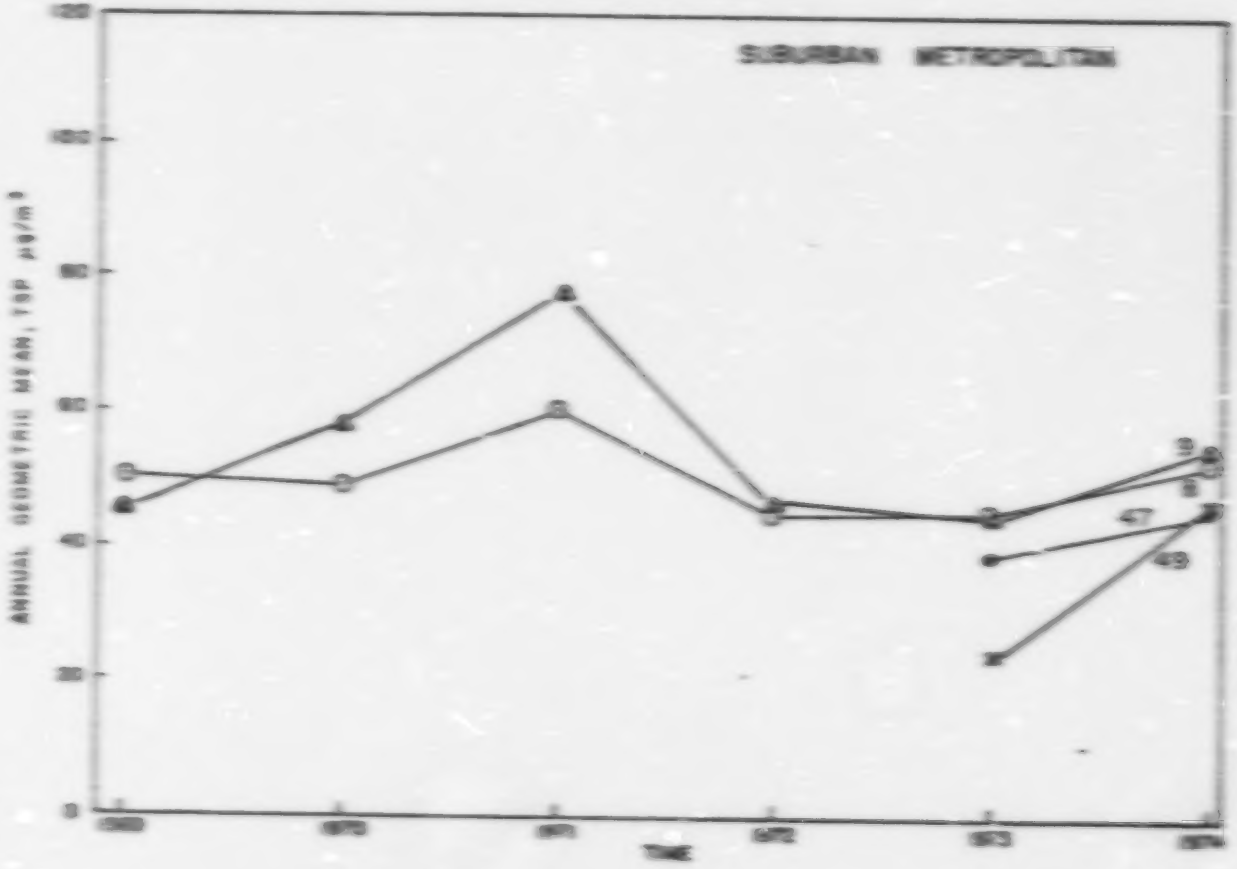


Figure 16. Annual geometric TSP means for suburban metropolitan Rhode Island

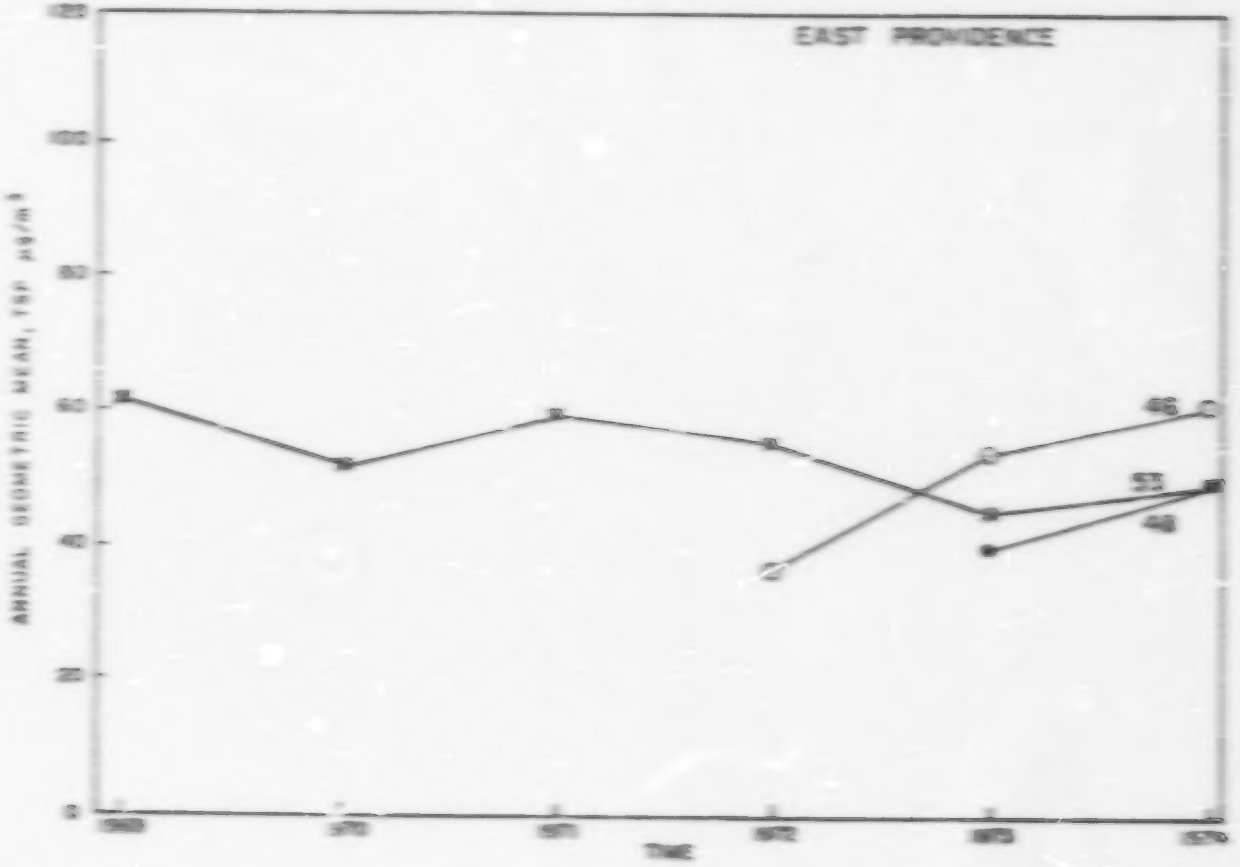


Figure 15. Annual geometric TSP means for East Providence, Rhode Island

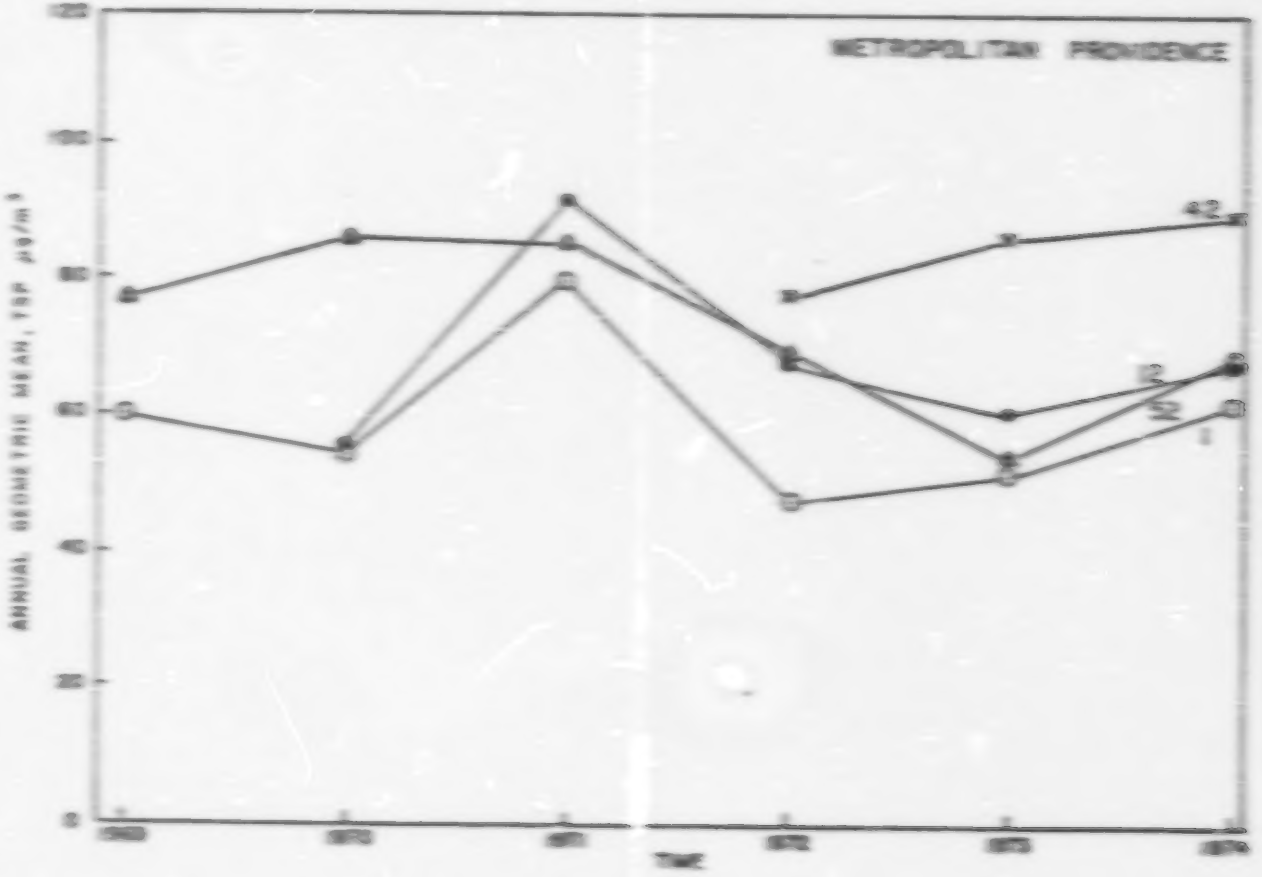


Figure 20. Annual geometric TSP means for Metropolitan Providence, Rhode Island

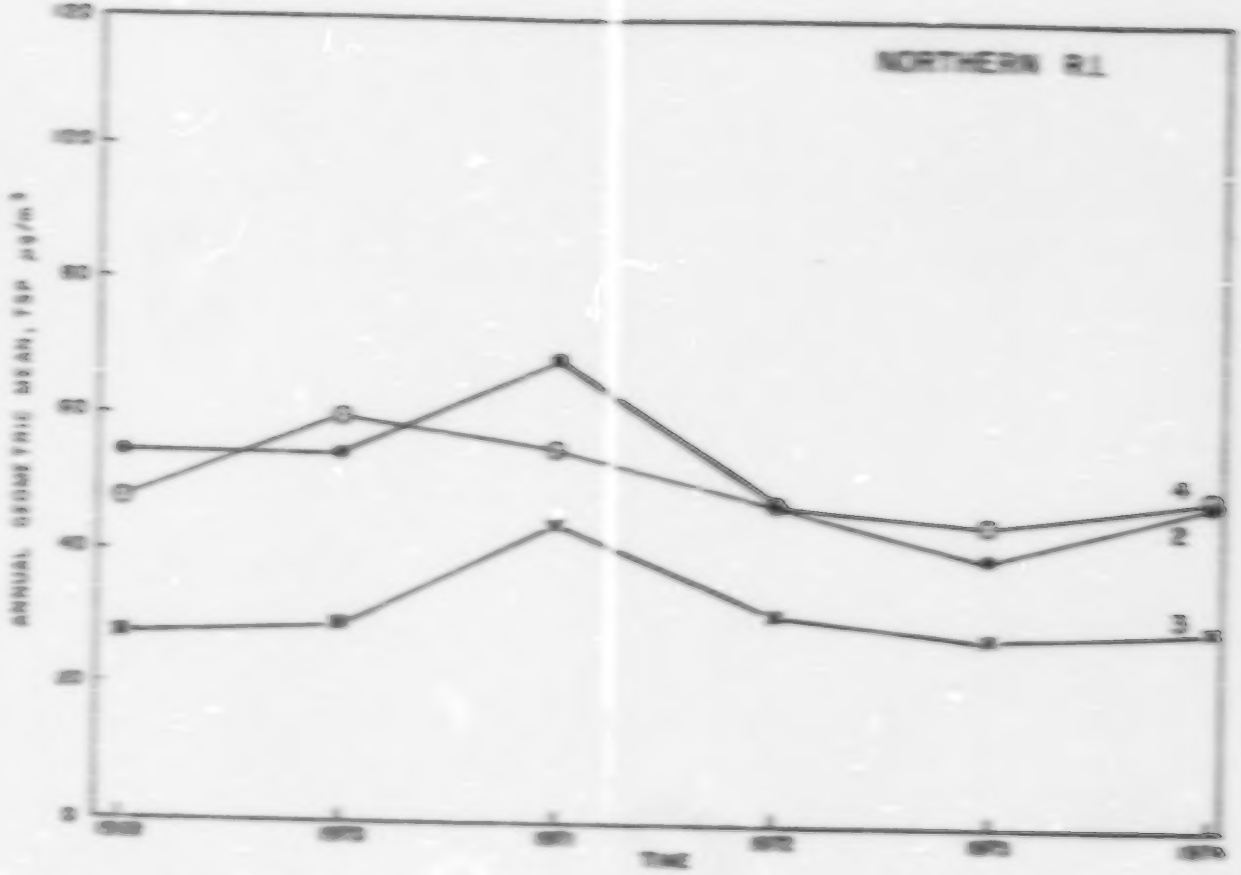


Figure II. Annual geometric TSP means for northern Rhode Island

APPENDIX A

PARTICLE CHARACTERIZATION

For most of the study cities, members of the GCA study team acquired hi-vol filters from the 1974 filter banks of the cognizant local agencies. In addition, several filter samples for 1974 and selected earlier years were obtained from state and federal filter banks. Although some filters underwent chemical and/or detailed physical analysis, the principal purpose of obtaining filters was to utilize optical microscopy to identify each of the constituents that comprised more than 5 percent of the particulate mass. The selected filters, which were representative of several different site types and TSP levels within each study area, were returned to a clean room at GCA/Technology Division and carefully inspected for artifacts and evidence of sampler or filter malfunctions.

Each filter was then assigned a randomly generated five digit number which served as the only identifier for the filter sample so that each analyst had no information concerning the city, site, TSP loading or probable local sources associated with the sample. Furthermore, the use of two laboratories for the microscopy, coupled with the randomly generated identifying numbers, permitted a fairly comprehensive quality control program in the form of blind replicate analyses. Since both laboratories utilized more than one analyst, these procedures resulted in as many as four microscopists observing samples from the same filter and, in some cases, the same analyst examining replicate samples from the same filter as many as three times.

The results of this quality control effort, which are presented in Volumes I and II, warn against relying very heavily on the results of any one filter analysis. However, the random match-up between analyst and filter sample should minimize systematic bias in composited results.

Twenty-five filters from five sites were selected for analysis in Providence, and Table A-1 summarizes the meteorological data for the selected sampling days. To gain some insight into the contribution of secondary particulates, much of which is too small to be observed by the microscopist, the annual average sulfate and nitrate concentrations for the NASN site are shown in Table A-2. The results for each of the filters submitted for routine analysis are presented in Table A-3. The results for the filters at each site have been averaged to give a composite of the particulate composition as shown in Table A-4. Nine filters underwent replicate analyses, and the results are presented in Table A-5.

The composite particulate characterization for all filters from Providence that underwent routine analysis, presented in Table A-6, shows that most of the TSP is composed of minerals. The average percent minerals reported, however, is not atypical in terms of the other cities studied, with Providence ranked eighth out of the 15 cities. The amount of combustion products is also quite typical, with Providence ranked ninth highest in that category. The predominant type of combustion product identified was oil soot, an expected result in view of the predominance of oil as a fuel in the area. In fact, the identification of coal soot and fly ash, although in very small amounts, was somewhat surprising because coal is not believed to be utilized at all in the Providence area.

The average percent rubber reported is high, with only one other city included in the study exceeding Providence. The composite average of 16 percent rubber is not the result of a few isolated observations;

indeed, 23 of the 25 filters analyzed were reported to have rubber on them. The highest observed percent rubber content of any sample was 35 percent at the Westminster Street site which is located 100 feet above street level. The Dyer Street site, which had the highest 1974 TSP levels in the Providence AQCR, also had the highest average rubber content. This finding is strongly supportive of the belief that the high TSP levels at Dyer Street are adversely affected by the proximity of the site to Interstate 195.

Three of the filters from Providence were also submitted for determination of particle size as a function of particle type, as shown in Figures A-1 through A-3. One of these samples was also selected for detailed physical analysis, and the results are presented in Table A-7.

Table A-1. METEOROLOGICAL DATA ON SELECTED SAMPLING DAYS (THEO. FRANCIS GREEN STATE AIRPORT, PROVIDENCE)

Date	Precipitation, in.		Wind speed, mph		Wind direction, deg	
	Day of obs.	Preceding day	Average	Resultant	3-hour observation	Resultant
1/26/74	0.01	0.06	11.1	7.5	70, 320, 330, 210 270, 330, 300, 230	300
6/15/74	0	0	9.6	5.7	350, 350, 360, 30 30, 180, 300, 360	360
9/20/74	0	T	7.5	5.5	180, 210, 150, 170 220, 190, 190, 150	200
10/16/74	0	T	9.6	7.5	C, 350, 300, 270 170, 170, 180, 180	190
10/25/74	0	0.10	9.5	7.7	290, 320, 350, 330 310, 300, 230, 250	300
11/01/74	0	0.19	9.2	8.5	290, 230, 230, 220 260, 250, 270, 270	260
11/19/74	0	0	6.8	5.5	280, 320, 230, 350 310, 290, 260, 250	290
12/19/74	0.01	0	9.1	8.6	270, 280, 270, 250 260, 210, C, 250	260

Note: C = Calm
T = Trace

Table A-2. ANNUAL AVERAGE CONCENTRATIONS OF SULFATE AND NITRATE IONS AT THE PROVIDENCE, RHODE ISLAND, NASN SITE NO. 410300001 ($\mu g/m^3$)

Year	Sulfate		Nitrate	
	Arithmetic mean	Geometric mean	Arithmetic mean	Geometric mean
1973	11.11	10.16	1.50	1.17
1974	10.51[a]	9.77[a]	2.35[a]	1.91[a]
1975	9.36[a]	8.87[a]	2.92[a]	2.35[a]

[a]Indicates insufficient data for statistically valid year.

Table 4-3a. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PROVIDENCE AND VICINITY (WESTMINSTER STREET – NO. 11)

Table A-3b. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PROVIDENCE AND VICINITY (THURSTON BURGESS SCHOOL – NO. 46)

Table A-3c. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PROVIDENCE AND VICINITY (CHARLESTOWN GENERAL HOSPITAL - NO. 47)

Site																			
Site No.																			

Table A-3d. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PROVIDENCE AND VICINITY (OPEN STREET – NO. 42)

Date	24 October 1974			1 November 1974			31 November 1974		
TSP ($\mu g/m^3$)	42			111			48		
Component	Number (%) matches	Size range, μ	Avg. size, μ	Number (%) matches	Size range, μ	Avg. size, μ	Number (%) matches	Size range, μ	Avg. size, μ
Minerals	(5)	1-42	19	(8+)	1-40	12	(5+)	2-40	12
Quartz	1+			4			2+		
Silicates							1		
Feldspars				1+					
Hematite	1			1					
Mica									
Combustion Products	(14)	1-31	3	(5)	1-15	3	(4)	2-15	7
Soot:									
All							4		
Dark									
Tarry and cenospheres	1+		3						
Others:				3+					
Fly ash									
Incinerator fly ash									
Burned wood									
Burned paper									
Rubber tire									
Biological Material	(3+)			(3+)			(3+)		
Pollen									
Spores									
Hairs									
Plants									
Misc. (desc.									
Cotton									
Miscellaneous	(3+)	1-120	41	(3+)	8-75	28	(3)	12-60	36
Iron or steel									
Rubber	1			2+			1		

Table A-3a. RESULTS OF FILTER ANALYSES FOR SELECTED SITES IN PROVIDENCE AND VICINITY (MASS SITE NO. 4203000[illegible])

Date	[illegible]			[illegible]			[illegible]			[illegible]		
TSP ($\mu g/m^3$)	[illegible]			[illegible]			[illegible]			[illegible]		
Determinand	Number of samples	Concentration range, $\mu g/m^3$	Arithmetic mean, $\mu g/m^3$	Number of samples	Concentration range, $\mu g/m^3$	Arithmetic mean, $\mu g/m^3$	Number of samples	Concentration range, $\mu g/m^3$	Arithmetic mean, $\mu g/m^3$	Number of samples	Concentration range, $\mu g/m^3$	Arithmetic mean, $\mu g/m^3$
Insoluble	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Quartz	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]			[illegible]		
Calcite	[illegible]	[illegible]	[illegible]							[illegible]		
Feldspars	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]					
Kaolinite	[illegible]	[illegible]	[illegible]	[illegible]			[illegible]			[illegible]		
Micas				[illegible]								
Hydrocarbon-like substances												
Combustion products	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]
Soot:												
Oil	[illegible]	[illegible]	[illegible]									
Coal	[illegible]	[illegible]	[illegible]							[illegible]		
Coke												
Cenospheres												
Oil ash												
Burned wood												
Burned paper												
Ammonium												
Biological material	[illegible]			[illegible]			[illegible]			[illegible]		
Pollen												
Spores												
Algae												
Insects												
Misc. fiber tissue												
Miscellaneous	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Iron or steel fiber	[illegible]	[illegible]		[illegible]			[illegible]			[illegible]		
Rubber	[illegible]			[illegible]			[illegible]			[illegible]		

Table A-4. COMPOSITE SUMMARY OF FILTER ANALYSES FOR SELECTED SITES IN PROVIDENCE AND VICINITY

Site	Site No. 12		Site No. 50		Site No. 57		Site No. 52		WPRO Site	
No. of filters	8		6		6		1		4	
	Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent		Quantity, percent	
Components	Average	Range	Average	Range	Average	Range	Average	Range	Average	Range
Minerals	(60)	31-87	(72)	37-92	(61)	31-85	(38)	28-51	(79)	61-89
Quartz	39	16-65	51	25-71	35	11-71	27	20-35	55	35-81
Calcite	11	2-31	7	0-20	6	2-10	2	0-3	9	0-30
Feldspars	2	0-6	3	0-5	7	0-20	5	2-8	10	0-15
Hematite	6	0-10	10	5-20	10	5-18	3	1-9	2	0-15
Mica	2	0-10	2	0-5	0	0-15	<1		1	0-2
Other									2	0-9
Combustion Products	(21)	5-60	(19)	8-61	(25)	5-68	(38)	16-50	(9)	2-11
Soot:										
Oil	15	0-39	15	0-61	11	0-30	13	8-23	2	0-10
Coal	1	0-5			2	0-11	6	0-15	1	0-5
Fine soot	5	0-27	2	0-5	6	0-13	6	0-8	1	0-10
Fibers	1	0-3	1	0-5	5	0-29	2	0-6	1	0-2
Cellulose fibers							11	10-15		
Vegetable tissue										
Pollen										
Spores										
Fungi										
Starch										
Other plant tissue	4	0-10								
Biological Material	(1)	0-1	(1)	0-3	(1)	1-6	(1)	1-2	(1)	
Pollen	<1		<1		<1		<1		<1	
Spores	<1		<1		<1		<1			
Fungi	<1		<1	0-1	<1		<1	0-2	<1	
Starch	<1		<1		<1				<1	
Other plant tissue	1	0-1	1	0-6	1	0-4	<1	1-1	<1	
Miscellaneous	(19)	5-35	(8)	0-18	(12)	1-28	(21)	10-30	(12)	5-28
Flakes of steel	1		<1		<1		<1		<1	
Other	19	5-35	8	0-18	12	0-28	21	10-30	12	5-28

Table A-5. RESULTS OF REPLICATE ANALYSES OF PHYTOPLANKTON STUDIES

Table A-6. CITYWIDE COMPOSITE SUMMARY OF FILTER ANALYSES IN PROVIDENCE

No. of filters	25	
	Quantity, percent	
Components	Average	Range
Minerals	(64)	28-92
Quartz	39	11-71
Calcite	7	0-31
Feldspar	7	0-45
Hematite	8	0-18
Mica	3	0-15
Other[a]		
Combustion products	(22)	2-68
Soot:		
Oil	12	0-61
Coal	2	0-15
Misc. soot	4	0-27
Glassy fly ash	2	0-29
Incinerator fly ash	1	0-14
Burned wood		
Burned paper		
Magnetite		
Carbon black	1	0-10
Other		
Biological material	(1)	0-5
Pollen	<1	
Spores	<1	
Paper	<1	0-2
Starch	<1	
Misc. plant tissue	1	0-4
Lead trichomes		
Miscellaneous	(13)	0-35
Iron or steel	<1	
Rubber	13	0-35
Other		

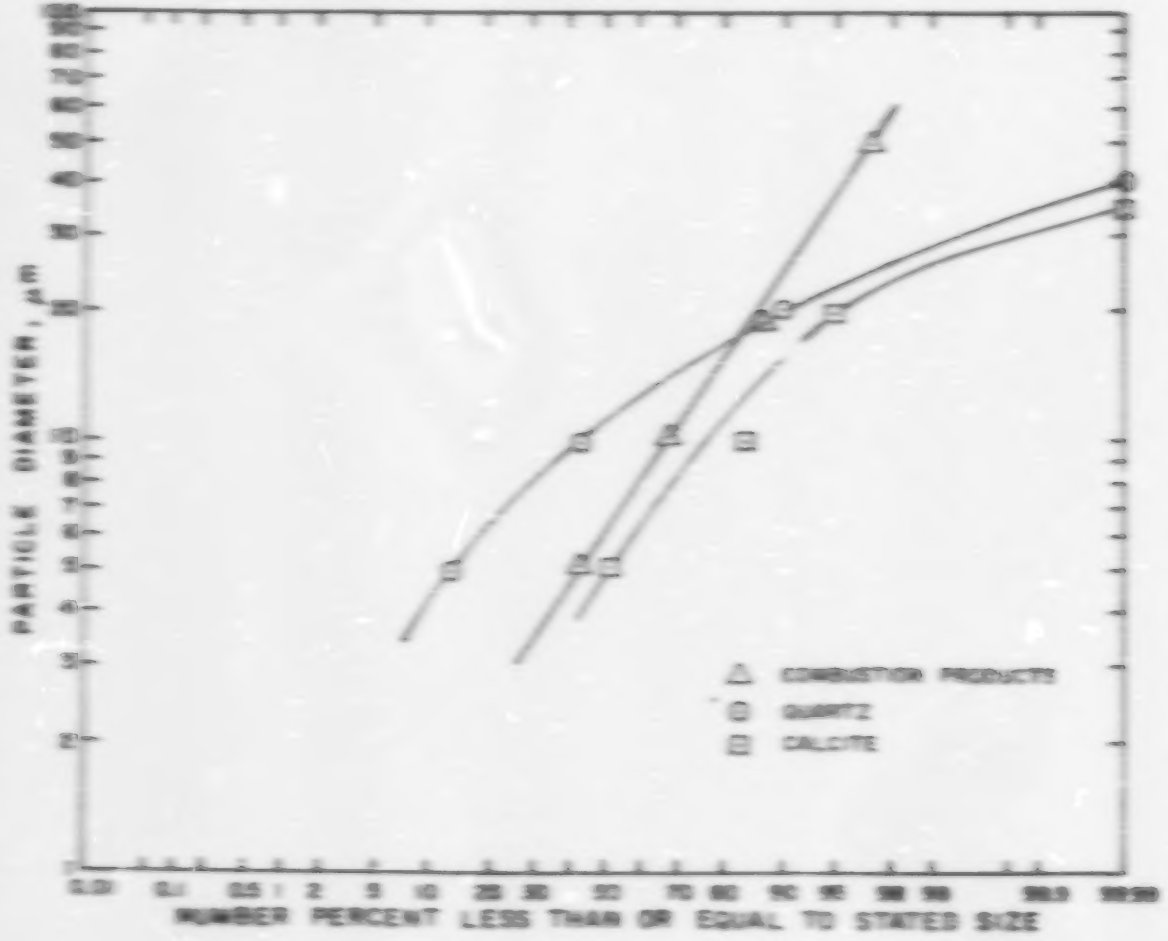


Figure A-1. Cumulative particle size distributions for three particle types, Westminster Street site, Providence, August 15, 1974

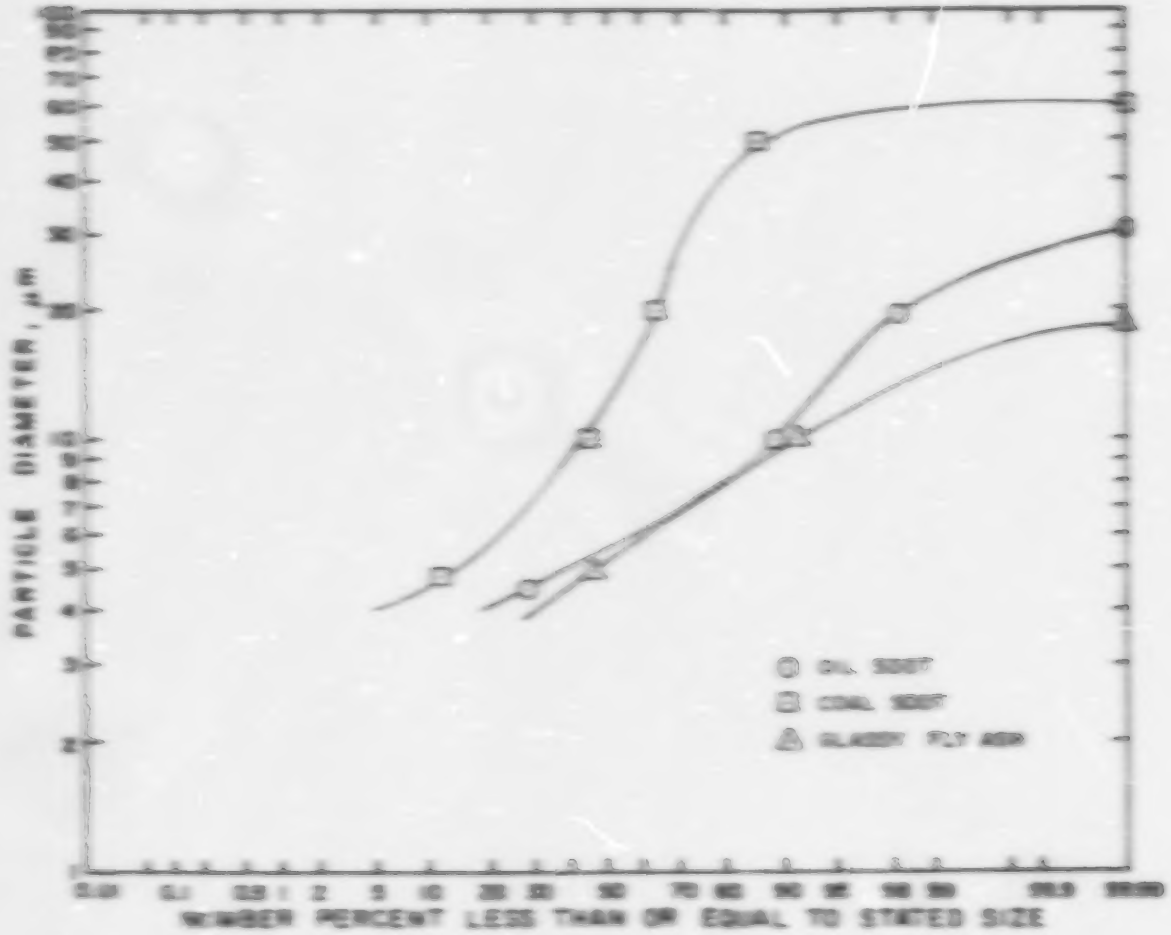


Figure A-2. Cumulative particle size distributions for three particle types, Tristam Burges School, Providence, September 20, 1974

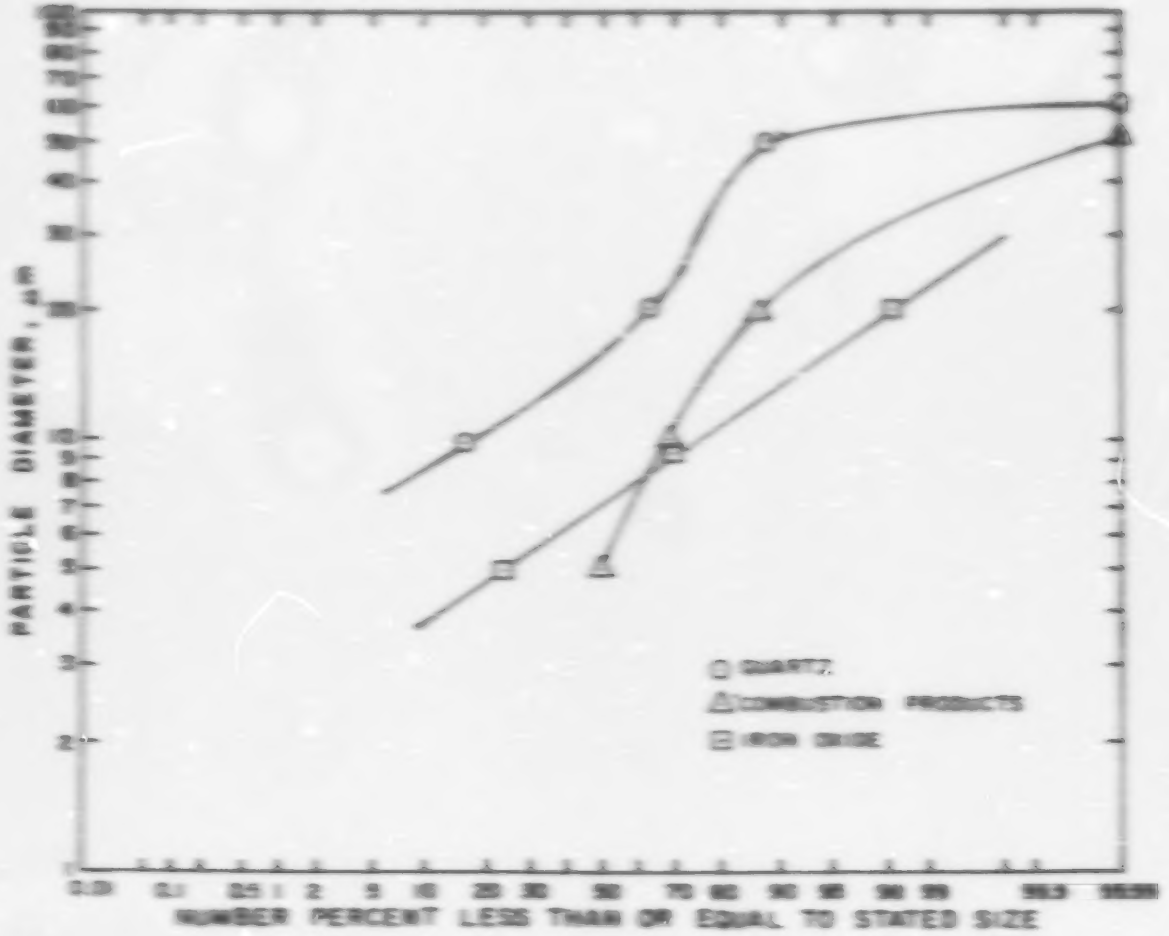


Figure A-3. Cumulative particle size distributions for three particle types, Dyer Street, Providence, November 19, 1974

Table A-7. DETAILED PHYSICAL ANALYSIS: DYER STREET, PROVIDENCE, NOVEMBER 19, 1974

A. Quartz confirmed by dispersion staining and (-) uniaxial interference figure. EDXRA shows only silicon and trace of iron (from hematite).

C. Calcite confirmed by EDXRA - shows only calcium.

E. Oil soot confirmed (as far as possible, due to small particle size and variability of fly ash due to operating conditions) by petrography, morphology and especially EDXRA analysis showing: aluminum, silicon (both from clay + fuel-ash [combined] calcium, sulfur, chlorine (trace as normal constituents of oil ash)) iron and vanadium (normal constituents of oils). The major constituent was carbon.

D. Rubber was confirmed by its elastomeric nature, surface appearance and EDXRA spectrum showing mostly carbon with minor amounts of calcium, aluminum, silicon (all probably from fuel-ash products), sulfur, chlorine, iron, titanium, and zinc.